THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVI. No. 7. JULY, 1955

Electrical Earthing Systems and Corrosion

By L. P. SCHAEFER. (From *Applications and Industry* (*AIEE*), *U.S.A.*, No. 18, May 1955, pp. 75-83, 5 illustrations.)

THE functional objectives in designing an electrical earthing system are to provide a low resistance path for the fault currents to earth, and to provide safety for personnel by limiting the potentials to safe values. This is normal earthing practice, and underground corrosion has generally been neglected until a considerable amount of damage has occurred to the primary structure.

The earth is tremendous in cross-section and consequently, when considered as a conductor between two electrodes, it has a relatively low electrical resistance. However, an electrode placed into the earth will have a finite resistance value, depending on the texture, aeration, moisture, and dissolved salts in the soil surrounding the electrode.[1,2]

Corrosion underground is an electro-chemical reaction, often caused by dissimilar metals, dissimilar electrolytes, and stray currents. Dissimilar-metal corrosion is set up as a result of two metals, such as copper and lead, which are electrically connected together and immersed in an electrolyte, such as a soil. Corrosion resulting from dissimilar electrolytes is the type that occurs when soils of different resistivity surround the same section of buried metal pipe. Stray-current corrosion occurs when stray electric currents leave a buried metal structure. Corrosion is halted when the corrosion currents leaving the structure are nullified by externally applied current.

EARTH-RESISTIVITY MEASUREMENTS

The earth as an electric circuit element can be measured in terms of its electrical resistivity. This value will vary with a number of factors, including depth below grade, where lower values are usually obtained as the soil becomes more moist because of the level of the water table. However, higher resistivities are also often experienced with increasing depth when rock structures are encountered. The electrical resistivity of the earth varies between extremely wide limits and is a decisive factor in using the earth as a return conductor, such as for electrical grounding, corrosion, stray-current electrolysis, inductive interference, and lightning protection.

Earth-resistivity measurements are made by the standard 4-pin or Wenner method.[3] This method uses four pins set up on grade where the two outside, or current, electrodes are 3D ft apart and the two centre, or voltage, electrodes are D ft apart, where D is the distance between pins. The resulting values of voltage and current when used in the relation 191 DE/I give the soil resistivity in ohms per cubic centimetre (ohm-cm). The particular spacing on the surface of the ground produces the average soil resistivity to the depth below grade corresponding to the surface spacing.

The analysis[4,5] for this method is as follows :—

Suppose the current I to enter the ground at the point electrode No. 1 (Fig. 1) of radius s ; area $= 2\pi s^2$ and radial current density $\mathcal{J} = I/2\pi s^2$. Let ρ = soil resistivity in ohm-cm. Then, the electrical intensity $E(s) = \rho I/2\pi s^2$, and the potential between s and an infinite point is

$$V = \int_s^\infty E(s)\,ds = I\rho/2\pi s$$

The resistance of electrode No. 1 and an infinite point is

$$R(s) = V/I = \rho/2\pi s$$

The resistance of a circuit between electrodes 1 and 2, with a circuit between electrodes 3 and 4, is

$$\begin{aligned} R &= R_{13} - R_{23} - (R_{14} - R_{24}) \\ &= \rho/2\pi(1/D - 1/2D - 1/2D + 1/D) \\ &= \rho/2\pi D \end{aligned}$$

$$\rho = 2\pi DR,$$

where $R = V/I$.

Hence,

$$\rho = 191D\ V/I.$$

The depth to which the electrodes are placed into the earth will not affect the measurements, provided this distance is relatively small compared with the electrode spacing.

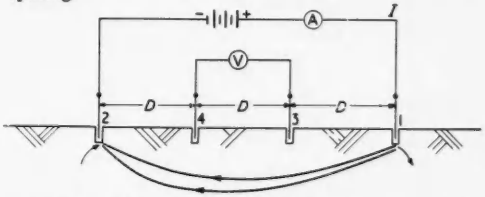


Fig. 1. **Four-electrode method of measuring soil resistivity.**

Usually, the depth of the electrodes in the soil is not important ; however, if poor electrical contact is made with the earth, a resulting low instrument sensitivity will be obtained. Because of the wide variations in soil resistivity, it is almost always necessary to measure the resistivity in the precise locality under consideration. These same types of soil-resistivity tests can be used for geophysical prospecting, but their interpretation requires more detailed analysis than is necessary for the electrical grounding problem.

The electrode configuration which makes electrical contact with the soil should provide the lowest ohmic resistance feasible from an economic standpoint. This is true for electrical grounding systems, and is also a basic design criterion for ground beds which supply corrosion control for buried metallic structures. This concept makes it possible to combine good electrical earthing and adequate corrosion control.

LEAD CABLES IN DUCTS

The various types of underground lead-cable sheaths exposed to external corrosion include electric power and lighting cables, telephone and fire-alarm cables. Corrosion of lead-sheath cables is due to several causes, such as : (1) Small anodic and cathodic areas of lead, due to splices, scratches, and abrasions ; (2) alternate wet and dry duct-runs ; (3) galvanic effects due to copper bond straps, ground connections, or proximity to other metals ; and (4) stray-current effects from electrified railways, industrial chemical operations, and other sources.

In a number of known corrosive locations, it has been the practice in the past to use a protective neoprene sheath over the lead sheath to prevent sheath corrosion.

This is a satisfactory mitigating measure against local cell action, dissimilar soil environment, and galvanic cells. The stray-current problem, however, may require a complete system study, resulting in the proper use of insulating splices and possibly polarized forced-drainage bonds. The neoprene-sheath construction has proved satisfactory in providing a moisture-proof coating which apparently has a relatively small deterioration with age. It has been reported that polyethylene coatings also are most satisfactory.[6]

The fundamental corrosion cell consists of two electrodes separated by an electrolyte on the internal circuit and electrically connected together on the external circuit. The coating practice just described supplies a high-resistance electric barrier to current flow on the internal circuit, thus halting the corrosion. The insulated jacketed cable, on the one hand, requires adequate grounding, because most certainly none will be obtained as a result of the underground cable run. The bare lead-sheath cable, on the other hand, will have a fairly low ground resistance as a result of wet ducts and low soil resistivity. To this is added an earthing system to ensure a low ground resistance value. The grounding system will generally consist of a bare copper ground bus of 500,000-circular-mil size or larger located in a spare duct or embedded in the concrete envelope of the duct-runs. Another common practice is to locate terminal and switching equipment in underground vaults with a considerable ground mass, all of copper, located at the vault. Both the lead sheath and the copper ground rods and interconnecting cables are bare. A low-resistance contact with the soil has thus been obtained for the earthing system. This is usually less than 5 ohms at the terminal equipment in the vault, and less than 25 ohms at each ordinary manhole. For the galvanic corrosion-cell circuit, there are these low resistance contacts with the earth, plus the driving potential of 0·5 to 0·6 V from the lead-copper combination. The lead sacrifices to the copper, thus prolonging the life of copper grounds at the expense of lead-cable sheaths.

The stray-current problem on lead-sheath cables from electrified railways is rather complex. The track resistance to earth, the cable resistance to earth, soil resistivity, the geometry of the two systems, and rail-bond continuity are all items affecting the magnitude of induced stray currents on the cables. The system study involves track-to-cable or track-to-soil potential recordings at all cross-over locations and all areas where the track and cable runs are adjacent. On the basis of these recordings, the locations of "natural" drainage bonds are determined, usually near the generating stations. Also, it is ascertained by the recordings whether the drainage bonds are adequate to supply corrosion protection or whether cathodic protection in the form of rectifier-driven "forced" drainage is to be added to the system of bonds connecting the cables and tracks.

Where power-cable runs are bonded to a bare copper conductor in the duct envelope, or in a spare duct, there is certainly a problem in galvanic corrosion. Functionally, such a system may be very satisfactory from the standpoint of supplying a low resistance ground for operation of system relays. From the point of view of corrosion, the very minimum of maintenance would require that the duct-runs be pumped dry at all times. Where low soil resistivities prevail, it may be necessary to cut the lead cables free from the copper ground bus and apply new grounding, using heavily zinc-coated steel rods and cathodic protection.

An example of cathodic protection on an underground lead-cable system is illustrated in Fig. 2. Sample calculations are as follows :—

A vertical anode buried in the soil has the following general equation for the resistance of the anode :—

$$r = 0{\cdot}0324\,\rho/L \text{ ohms} \quad \ldots \quad \ldots \quad (1)$$

where L = length of anode, ft ; ρ = specific resistivity of soil, ohm-cm ; r = resistance of the anode to remote ground ; and N = anodes in a straight line at a separation S ft and connected in parallel.

The combined resistance is

$$R = r/(KN) \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$K = 0{\cdot}6$ where $S = 20$ ft, $0{\cdot}77$ where $S = 40$ ft, and $0{\cdot}87$ where $S = 60$ ft.

(1) *Basic data:*— Underground lead telephone cables are to be protected against corrosion by cathodic protection. Surface area of cables and ground bed involved = 5640 sq ft. The current density of 0·0003 A/sq ft was determined by test to supply a change of 0·2 V in the negative direction, as measured from the cable to a lead shoe electrode in contact with the soil.

(2) *Total current required* = $5640 \times 0{\cdot}0003 = 1{\cdot}69$ A, or roughly 2 A.

(3) *Resistivity of the soil involved* = 780 ohm-cm.

(4) *Impressed current system design* :— (a) The anode resistance is computed, using eq. (1),

$$r = 0{\cdot}0324/L = (0{\cdot}0324 \times 780)/8{\cdot}7 = 2{\cdot}89 \text{ ohms},$$

using anodes 3 to 4 in. in diameter by 80 in. in length, with an effective length of 8·7 ft, as a result of the coke-breeze backfill, and a separation of 20 ft. The ground-bed resistance, from eq. (2), is

$$R = 2{\cdot}89/(0{\cdot}6 \times 3) = 1{\cdot}6 \text{ ohms}.$$

(b) Assuming a 3% voltage drop in the feed wire (a good general practice because of the relatively large amounts of current encountered) the voltage to be supplied by the rectifier is

$$E - 0{\cdot}03 = IR$$
$$0{\cdot}97E = 2 \times 1{\cdot}6$$
$$E = 3{\cdot}3 \text{ V}.$$

A rectifier with a d.c. output of 5 or 6 V and a rating of 10 A will be chosen for this application.

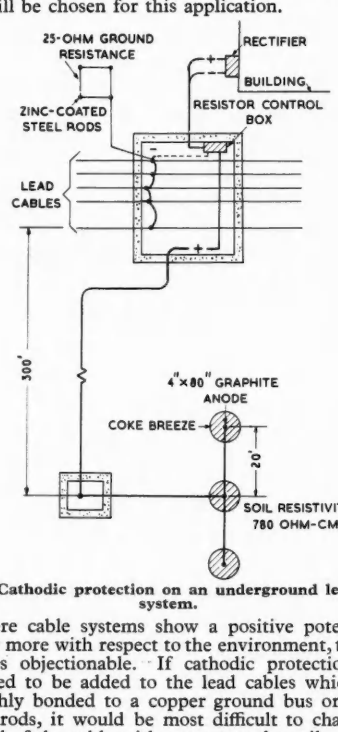


Fig. 2. **Cathodic protection on an underground lead-cable system.**

Where cable systems show a positive potential of 0·3 V or more with respect to the environment, the condition is objectionable. If cathodic protection were attempted to be added to the lead cables which were thoroughly bonded to a copper ground bus or copper ground rods, it would be most difficult to change the potential of the cable with respect to the soil. This is because of the short-circuit path between the cathodic-

protection anodes and the many ground rods or ground bus, consequently making it difficult for cathodic-protection current to reach the cables themselves.

The corrosion problems for underground-telephone and fire-alarm cables are approximately the same as those for power cables; however, the earthing is somewhat different. Telephone earths are at exchanges and subscriber locations for operational purposes. The dissipation of lightning surges, before damage results to the cables, depends on values and locations of grounds, spatial location of cable runs, and soil-resistivity values of areas through which the cables run. Corrosion control on telephone cables is somewhat simpler than for electric power cables, because the earthing system is not so expensive and because the flash-overs due to fault currents are absent.

Earthing of Substations

Electric substations are subject to external corrosion on non-current-carrying parts, such as housings, and above and below grade structures. The mechanical parts of air switchgear are subject to corrosion under conditions of moisture and weathering. This is also true of bus structures where dissimilar metals are involved.

Substation earthing systems are closely associated with corrosion problems. A low soil resistivity of 1500 ohm-cm or less makes it relatively easy to provide low-resistance grounding; however, corrosion of the buried lead cables, column footings, steel conduit, etc. might be severe. From values of 15,000 to 150,000 ohm-cm, soil corrosion is reduced in severity, but it is most difficult to secure a low-resistance ground without resorting to the use of an elaborate and expensive grid.

Major-distribution substations usually require a ground-resistance value of less than 1·0 ohm; minor substations are less than 5 ohms, and small-capacity distribution equipment, such as transformers and switchgear, are grounded at less than 25 ohms. There are several available methods of measuring the ohmic value of substation grounds.[7] Geometrically speaking, the larger the grounding grid, the more elaborate is the test set-up required to measure the resistance value.

Major substations will require low-resistance earthing to provide for fast relaying to clear faults, and for lightning and surge protection. To achieve these low values, considerable quantities of bare ground rods and bare connecting conductors are used. The ground non-current-carrying ferrous housings of transformers, switchgear, voltage regulators, etc. can usually be mounted so that no galvanic circuit prevails between the steel housings and the copper grounding system. Steel frame columns can be coated with bituminous paint and set in concrete to reduce corrosion possibilities. Care must be taken that no salt is used with the concrete, if poured in freezing weather. Underground cable and conduit systems should be brought into the substation in fibre ducts set in concrete. The duct-runs should be kept free from water as part of a regular maintenance programme. Underground cables and conduit should be earthed separately by means of heavily zinc-coated steel rods, cathodically protected. The underground cable and conduit systems should also be coated with neoprene for the cables and a good bituminous-paint system for the conduit, where the substation is located in a low soil-resistivity area. The coating provides an electrical resistance in the galvanic corrosion-cell circuit, reducing the possible galvanic current which may flow. If the galvanic current is completely nullified, corrosion will not take place.

An electric substation using a considerable amount of copper in a grounding system makes it extremely difficult to bring the other underground structures in the vicinity under cathodic protection. This is true because the copper ground system soil-to-structure potential must exceed 0·55 to 0·60 V, as measured to a copper-copper sulphate reference half-cell, before any changes in the potential of steel structures to the soil can be obtained. This is related to the location of the two metals in the electromotive-force series. Consequently, the steel and lead in the substation yard, especially if their surface areas are small compared with the copper grid, will receive little or no cathodic protection current, while the copper grid system will be very much over-protected.

The major consideration for earthing conductors and rods is the ability to handle large fault currents up to 30,000 A for periods of 30 to 50 seconds without burning. Lightning surges, with durations in the micro-second range, are more of a mechanical than a heating problem. Consequently, a material, other than copper, which might be used for a ground bed must have good current-carrying qualities and utilize fittings which are of the rigid clamp type. Usually, the bare conductors connecting the ground rods contribute towards increasing the conductivity of the ground bed. Where the ground rods alone can supply the proper resistance, the connecting cables can be of copper, but these should be insulated with a neoprene sheath suitable for direct burial. Careful design attention should be given to the proper insulation of the connectors used to clamp the cable to the ground rods.

The remaining consideration is given to the proper choice of ground-rod material. Zinc is used for ground rods, and is recommended in the 25-ohm range. Where lower resistance grounds are required to handle fault currents, a non-amorphous material is recommended. This choice is heavily zinc-coated steel rods. The ground rods in turn are then cathodically protected by zinc anodes. Such a system will not only provide corrosion mitigation for the grounding system but will help to protect the other buried structures and also to aid in reducing the total ohmic resistance level of the ground bed. Magnesium can be used as an anode material in the place of zinc, if a greater driving voltage is desirable.

Earthing of Tower Lines

The problem of obtaining low-resistance earths at tower and pole locations is the same as that for the previous structures described. Rights of way and costs, which must be kept to reasonable values, are some of the problems in establishing low-resistance earths. In many locations, where the subsoil or rock conditions prevent the use of long ground rods, it is necessary to use multiple short rods, buried horizontal wire, or a counterpoise system. Shallow grounds are subject to variations in resistance, caused by changes in temperature, such as frozen ground in the winter, or the moisture conditions of the soil. The tower-footing resistance for a transmission line will depend on the desired lightning performance of the line. A desired value of not over 10 ohms is not uncommon for tower-footing resistance. Primary distribution lines will have a desired pole resistance value of from 20 to 80 ohms, depending on the frequency of the grounding.[8]

Steel tower footings are subject to soil corrosion, dissimilar metal corrosion as a result of copper grounds being connected to the towers to secure low ohm-resistance levels, long line currents as a result of dissimilar soil environments through which the transmission line footings are located, and stray-current electrolysis as a result of adjacent electrified railways and cathodic protection on pipe lines near the transmission lines.

Steel tower footings are subjected to considerable soil corrosion if they are located in soils with resistivities of less than 1500 ohm-cm, and such soils make it possible to supply a low-resistance ground to the tower. Galvanic corrosion, as a result of bonding dissimilar metals, usually zinc-coated steel and copper, results in a rapid deterioration of the steel. Where the tower resistance value of, say, 10 ohms is obtained by copper ground rods, the zinc coating on the steel tower footings will act as an

efficient sacrificial anode to protect the copper ground rods. As soon as the zinc coating is stripped, the steel tower footing will also start corroding. Where the transmission line leaves the substation, which contains a considerable amount of copper in the earthing grid, as many as 50 to 60 towers have been affected by the substation ground mass.

Long line currents, as a result of the dissimilar soil environments through which the transmission line passes, are produced in the earthing system of the transmission line. These direct currents enter the system at the towers located on high ground, where the soil is less moist and has a higher electrical resistivity. The galvanic currents then leave the earthing system at the low points in the transmission line where the soil resistivity has a lower value.

Stray direct currents superimposed on the transmission-line grounding system from sources such as electrified railways, or as a result of cathodic protection installations on pipe lines, tanks farms, and other structures, usually require system studies for a proper solution. Stray earth currents from any source will return to the generating source by any adjacent low-resistance path. The mitigating measures necessary to prevent stray-current electrolysis of tower footings usually require consideration of a number of factors, due consideration being given to lightning and fault currents.

Power-transmission lines can also be a source of damaging currents for buried pipe lines where insulating couplings, adjacent to or crossing under the transmission line, are involved. The pipe lines, by induction, become part of the transmission-line ground counterpoise system. Large currents which occur as a result of lightning flash-overs and phase faults are induced on the buried pipe line, and the writer has measured as much as 80 A of alternating current induced on 6-in. piping running parallel to a 230-kV tower line for about 1 mile. Surge currents cause damage to the insulating flanges on the pipe lines by arcing across and fusing the flanges together.[9] Any kind of current on a pipe line transporting inflammable fluids can be a hazard, if the pipe line is cut or a section is removed and proper precautions are not taken.

Earthing of Industrial Plant

Electrical earthing systems in industrial plants should maintain a low potential difference between equipment and machine frames, metal enclosures, building structures, etc., to avoid shock hazard to personnel, and to provide a low resistance path to earth to ensure fast relay operation to clear fault currents before they become damaging. Electric currents as low as 0·05 to 0·17 A at 100 V can be fatal to personnel. A good ground structure in an industrial plant will limit voltages across cable insulation, motor frames, and peak voltages in transient effects, and permits rapid isolation of faults.[10]

Earthing for industrial plants will follow the same general procedure as that for other installations. The best locations for the ground beds are determined by the soil-resistivity measurements, and these in turn supply design data necessary to define the ground beds. However, these better locations for the grounding system may not conform to the desired locations of substations or underground-cable manholes. A major industrial operation will have a considerable amount of underground structure. In a large industrial plant, there would be ample opportunity to use the underground piping for electrical earthing. From the standpoint of securing a good ground, this might be satisfactory. Actually, pipe grounds are not good practice, since the piping may be abandoned or relocated, or may have non-conducting pipe joints, as is often the case with cast-iron water and sewer piping.

The use of non-ferrous ground rods, such as copper, functionally will supply adequate earthing for an industrial plant. However, long corrosion-free life for the copper will be obtained at the expense of the underground steel and lead structures in a great many cases. On the other hand, the use of steel for ground rods presents a corrosion problem which obviously could not be solved by the use of some kind of coating on the steel ground rods. Consequently, cathodic protection in the form of sacrificial anodes of zinc or magnesium can be used to supply corrosion mitigation to the steel ground rods, as well as the other underground structures in the vicinity. At the time an industrial plant is being constructed, it is relatively easy to install sacrificial anodes designed for a 20-year life, along with the required ground-bed systems. If, after a plant has been in operation for 5 or 10 years, it is desired to revise the grounding system because of excessive corrosion repairs or other reasons, it may be more economical to use a rectifier-supplied ground-bed system and zinc-coated steel ground rods.[11,12]

Most industrial plants will have some sort of stray-current problem, if no attention has been given to its control. The source of these stray direct currents may be welding equipment, plating processes, battery-charging equipment, possibly some d.c. control circuits, and motor-generator equipment. The practice with welding equipment, which often causes trouble, is to ground one welding electrode to the building frame. This will superimpose the direct current onto the grounding system and, if the current leaving the earthing rods is large enough, considerable corrosion will result. Such stray direct current will cause internal heating in the substation transformers if allowed to continue unchecked. Control circuits using direct current, with one or the other polarity grounded, can readily superimpose direct current on the grounding circuits. Battery-charging equipment is subject to d.c. leakage, and the earth path can be of low resistance as a result of the available acid and acid fumes.

Lightning and Surge Protection

Direct lightning strokes are responsible for trouble on transmission lines. Grounded neutral systems have fairly low resistance paths to earth, and aerial telephone cables have lower failures from lightning because of the shielding effect of the sheath. If a lightning stroke has a crest value of 20,000 A, this current through a 5-ohm ground resistance produces a voltage drop of 100,000 V, and through a 25-ohm ground this current value produces a 500,000-V drop. About 90% of this voltage will appear in a radius of 6 to 10 ft around the ground electrode.[13]

The actual peak values of current from lightning strokes are maintained for a short period of 20 to 30 microseconds. The surge current resulting from the lightning flash-over producing a line-to-ground fault may last to 5 cycles, until interrupted by the circuit-breaker. Such fault currents require special precautions where cathodic protection systems are used in conjunction with electrical earthing systems.

Where sacrificial anodes are used to supply cathodic protection to the earthing system, no special fault-current provisions are required, since the anodes are an integral part of the earthing system. However, there are little or no data available on the impulse characteristics of commercial zinc or magnesium anodes, but it might be of considerable value to check the ground resistance of such anodes, using a surge generator and the required measuring instruments.

The use of rectifier forced-drainage systems in connection with earthing systems, or more usually for earthed underground-cable systems, requires some special techniques. Buried pipe lines which become, because of the geometry of the systems, either by inadvertent direct contact or by induction, part of the ground-conductor system of a power-transmission line will usually require spark-gap installations at the insulating flanges along the pipe line.

STATIC EARTHING

The adequate discharge of static electricity by earthing is a problem from a hazard standpoint, where explosive and inflammable materials are handled in connection with hospitals, fuel handling, ammunition depots, and many industrial processes. Hospital floors, which are conducting, usually require resistance values of the order of 100,000 ohms to 1 megohm between the floor and ground. Fuel-handling earths will be generally of the 25-ohm variety, with the attendant switching equipment suitable for hazardous locations. Earthing systems for ammunition depots are rather elaborate for each individual manufacturing building, and their ohmic values and complexity are rather similar to those for electric substations.

Earthing systems in hospitals, owing to their physical components, are generally not subject to corrosion. Fuel-handling earthing practice consists of cross-bonding the above-ground piping and the connection of the ground bus to suitable grounding grids, in order to prevent sparking in the presence of inflammable vapours. For such systems, the same types of corrosion problems will exist, with regard to dissimilar metals, cathodic protection, and stray currents, as have already been discussed.

Earthing systems at ammunition depots are designed to discharge electricity and to provide grounding for lightning. In addition to these precautions, other safety practices are used, such as washing down walls to discharge charged particles and to remove possible hazardous conditions.

REFERENCES

(1) R. RUDENBERG: *Electrical Engineering*, Vol. 64, Jan. 1945, pp. 1-13.
(2) C. JENSEN: *Electrical Engineering*, Vol. 64, Feb. 1945, pp. 68-74.
(3) F. WENNER: *NBS Bulletin*, Vol. 12, 1916, S258, p. 469.
(4) E. D. SUNDE: "Earth Conduction Effects in Transmission Systems." D. Van Nostrand Co., Inc., New York, 1948.
(5) E. R. SHEPHARD: "Subsurface Exploration by Geophysical Methods." *ASTM Standard No.* 96, Philadelphia, 1949.
(6) F. E. KULMAN: *AIEE Transactions*, Vol. 73, part III, Aug. 1954, pp. 745-760.
(7) AIEE Committee Report, *AIEE Transactions*, Vol. 73, part III, Apr. 1954, pp. 271-277.
(8) J. R. EATON: *General Electric Review*, Vol. 44, Aug. 1941, pp. 451-456.
(9) S. KLEINHEKSEL: *Petroleum Engineer*, Vol. 22, March 1950, pp. D87-D90.
(10) L. J. CARPENTER: *Electrical Engineering*, Vol. 73, March 1954, pp. 256-260.
(11) E. B. CURDTS: *Petroleum Industry Electrical News*, Feb. 1951. Reprinted for James G. Biddle Company, Philadelphia.
(12) W. E. COLEMAN and H. G. FOSTICK: *Heating, Piping and Air Conditioning*, Vol. 25, Apr. 1953, pp. 85-87.
(13) O. S. PETERS: "Ground Connections for Electrical Systems." *NBS Technological Paper No.* 108, 1918.

HOLLAND

Noise Reduction in the Design of a Diesel-Engine Test House

By P. A. DE LANGE and G. J. VAN OS.

(From *De Ingenieur*, Vol. 67, No. 24, June 17, 1955, pp. W.74-W.76, 2 illustrations.)

THIS article describes a sound-proof test house for diesel engines and the methods used for obtaining a high degree of attenuation in both the test house and in neighbouring buildings. Bearing in mind that the requirement was to design the building in such a way that no noise inconvenience would result to residents in neighbouring houses and also that it would provide acceptable conditions for personnel working inside the building, the first point to consider was whether there should be a common test house for all engines or whether separate testing enclosures for each engine would be preferable.

The advantages of the common test house are that it is an economical construction, easy to use and to supervise. On the other hand, as soon as an engine is running, it generates a high noise level, to which testers and fitters preparing any other engine in the vicinity are inevitably exposed. A solution, however, is to use movable acoustic screens. Moreover, the engines to be tested can be assembled elsewhere, and can then be brought in and mounted on their test beds just before the test. In this way it is seldom necessary for personnel to be near a running engine. With this arrangement, of course, it is necessary to design the test house with a large entrance door; however, a single door of this kind is fairly easy to insulate acoustically.

To determine the amount of noise reduction required both inside and outside the building, it was necessary to take a number of measurements in workshops with running engines. The results showed high noise levels over a wide range of frequencies, most engines having a noise level around 100 db.

On the basis of these data, and taking due account of the position of the building, i.e., its distance from neighbouring houses, and of the noise expected from various other sources in the same area, it was possible to assess the amount of noise reduction which should be satisfactory.

In view of the spectrum distribution of the noise, it was evident that a simple brick wall would certainly not be adequate. Accordingly, it was decided to employ a hollow type of construction for the outer walls, with an interior brick wall of normal thickness separated by a space of 5 cm from an exterior wall of half the thickness, the intermediate space to be subsequently filled with a suitable damping material. For the roof this type of construction could not be considered, and reinforced concrete beams, 15 cm in thickness, were used. This type of construction gives an attenuation which is approximately equivalent to that of a solid wall of one-and-a-half bricks in thickness, insofar as air-borne noise is concerned. These design features were fairly easily achieved, though difficulties arose in connection with the entrance doors and other openings (vents, air-intake and exhaust-gas ducts), which act as "short-circuiting" elements and considerably reduce the overall isolation. It was decided to use double doors, one for each wall thickness. These doors were of steel filled with concrete, each door weighing about one ton. To eliminate leakage around doors and window frames, use was made of rubber strips.

To reduce their sonic energy, the exhaust gases were passed through a plenum chamber acting as a low-frequency attenuator, while the high frequencies were suppressed by means of an absorption type of muffler. The conventional method of noise attenuation in ducts, i.e., lining the inside surfaces with absorbing materials, could not be used in this case, owing to the high temperatures involved. This method was, however, applied in the case of the air intakes.

With regard to noise reduction inside the test house, a sound-absorbing wall was provided between the actual test room and the separate control room. This partition was constructed in the same way as the external walls, with very carefully designed inspection ports and doors, sealed off at all weak points. In this case the requirements were easier to fulfil than for the outside walls.

After completion of the test house, numerous measurements were taken, both inside and outside the building, and with doors open and closed. It was found that the features provided in this building were fully satisfactory in providing substantial noise reduction.

CANADA

The Impact of Plastics on Engineering

By I. R. TAIT. (From *The Engineering Journal*, Vol. 38, No. 4, April 1955, pp. 411-414, 456.)

In this paper, the author, after outlining the history of the plastics industry, classifies the main groups of plastics and describes a number of types, together with their properties and most suitable uses. As such, although it does not present anything new, the value of this article to the average engineer, who cannot be expected to be conversant with all the possibilities offered by the various types of plastics, is that it presents in concise and convenient form a general guide to their properties, manufacture, and potentialities.

ALTHOUGH plastics are fairly new to engineering, they are rapidly growing in interest and importance. In contrast with natural materials, plastics are man-made, a generally accepted definition being :—" Any one of a large and varied group of materials, consisting wholly or in part of combinations of carbon with oxygen, hydrogen, nitrogen, and other elements, and which, while solid in the finished state, are at some stage in their manufacture made liquid or softened, thereby being capable of being formed into various shapes, usually through the application of heat and pressure, either singly or together."

The widespread and growing use of plastics in almost every phase of modern living and engineering is largely due to their unique combinations of advantages, among which may be mentioned their light weight, their good physical properties, their range of colour, and their adaptability to mass-production methods, often resulting in lower costs.

The history of plastics dates back to 1869, when Hyatt, in America, investigated materials to replace the scarce and expensive ivory in billiard balls. After some experimenting, he developed a material which gave the ball all the properties required. This was cellulose nitrate, or " celluloid," and in 1869 the first U.S. patent was issued describing one of the many compounds known to-day as plastics.

The discovery and preparation of cellulose nitrate itself, however, can be traced back to the early work of Braconnot in France in 1833, and that of Schoenbein in Germany in 1845. Parkes, in England, prepared various articles from a solution of cellulose nitrate and camphor during the period 1855-1865, but it was Hyatt who was the first to attempt to work with cellulose nitrate as a plastic mass rather than in solution.

It is amazing that cellulose nitrate, a material so hazardous to handle, so readily decomposed by heat, and so unstable to sunlight in the unpigmented form, stood alone in the field of plastics for many years. However, its many unique properties made it the best available material for many purposes, ranging from dental plates to photographic films and the window curtains of early automobiles.

It was not until 1910 that the next plastic was produced. This was Baekeland's " Bakelite," a phenol-formaldehyde plastic of the thermosetting variety. It was not, however, until the mid-1920's that interest in plastics as a *family* of materials developed. Thus, to indicate the growth of the plastics industry, the output in the U.S.A. and Canada in 1922 was only about 6 million pounds. This grew to 213 million pounds in 1939 and, with the impetus provided by World War II, reached 818 million pounds by 1945, while 1954 saw more than 2800 million pounds produced.

Considered for many years as substitutes, plastics have now reached the level of " respectability " held by metals, wood, and ceramics, and are now looked upon as fully fledged engineering materials, though it is doubtful whether they will ever replace the older materials completely. Steel and wood have properties lacking in plastics. On the other hand, plastics have properties of their own which cannot be matched by other construction materials. Plastics tonnage has already passed that of aluminium, the most popular of the non-ferrous metals, and is rapidly approaching that of glass. The rise of plastics production has already caused revolutions in many industries and in the thinking of engineers.

CLASSIFICATION AND PROPERTIES

A convenient classification of plastics can be made on the basis of their behaviour under the influence of heat, causing all of them to fall into one of two groups—thermoplastic or thermosetting. Thermoplastic materials are made up of very long molecular chains, held together by relatively weak physical forces, whereas the large molecules of thermosetting resins contain groups which react to join the molecules together permanently under the influence of heat. In the case of thermoplastics, heat reduces the effect of these weak attractive forces, and softening or melting results. The material recovers its solid state on cooling, but retains its ability to re-melt.

With thermosetting resins, temporary softening under heat is followed by the formation of a network of strong chemical linkages, binding the molecules together and making the structure permanently solid and resistant to heat. Although some plastics are converted into finished products without further additives, many can be modified by the use of fillers, stabilizers, plasticizers, extenders, and pigments to give them the properties desired for processing and specific uses.

It is possible to alter the properties of many plastics by the use of various fillers. Basic characteristics may be modified or special characteristics introduced. For example, fabric fillers used in thermosetting plastics lead to greatly increased strength. Of course, fillers may also serve to reduce costs by replacing more expensive materials. A good example of this type of filler is wood flour, which has been used in quantities as high as 80% in some products. In some plastics, stabilizers are used to offset degradation caused by heat. Many of these are quite expensive.

Plasticizers, either liquid or solid, are usually chemical compounds or resins with very low vapour pressures, and are added to some products up to 10 to 40% by weight in order to improve moulding properties, to increase plasticity and flexibility, and to augment resistance to moisture, chemicals, weathering, and other conditions. It is important to use the proper plasticizer for a particular plastic or for a specific application.

Extenders are low-priced materials which may be added to many compositions to decrease the quantity of plasticizer needed. Pigments for plastics products are generally selected on the basis of compatibility, light fastness, and thermal stability.

TYPES OF PLASTIC

Acrylic Resins :—

The acrylic resins, which include " Perspex," " Lucite," and " Plexiglas," are glass-like thermoplastic materials with light weight, formability, strength, weatherability, shatter resistance, optical clarity, wide colour range, and machinability. Although their surface hardness is comparable with that of aluminium, surface scratches show up more clearly on their glossy surfaces. They are used for watch crystals, aircraft canopies, lighting-fixture diffusers, decorative panels, outdoor signs, costume jewellery, etc. An interesting characteristic of acrylics is their ability to " pipe " or bend light. This finds application in illuminated spatulas and other medical instruments and in edge-lighted signs.

Alkyd Plastic :—

Alkyd plastic is a thermosetting material which is fast-curing and which has good dimensional stability, electrical insulation, and heat resistance. It has, however, low impact resistance, unless special fillers are used. Its widest application has been in enamels and paints, providing a high gloss, and as a durable coating for stoves, refrigerators, etc. Alkyd has now become available as a moulding material with interesting properties which suit it for such units as automobile distributor caps, circuit breakers, television tuning devices, and tube supports.

Amino Plastics :—

The amino plastics include melamine and urea types, which are thermosetting materials. They have unlimited colour range, good electrical properties, and resistance to organic solvents. Melamines are familiar in tableware and are also used widely for caps and buttons, hearing-aid cases, etc. They are also used for surfacing laminates for table tops, for baking enamel, and in textile and paper treatment. The urea types are moulded into such items as scale housings, lamp reflectors, radio cabinets, and electrical devices. In the resin form they are also employed in baking enamels, in paper and textile treatment, and in plywood adhesives.

Casein :—

Casein is a product of the protein of skim milk. When reacted with formaldehyde it forms a thermosetting material, a strong, rigid plastic which resists the effect of both impact and flexing. It is not adversely affected by contact with gasoline or dry-cleaning solvents. However, immersion in liquids for long periods at room temperature or short periods at boiling temperature will cause it to absorb water, swell, soften, and break easily. Casein-formaldehyde becomes more brittle as temperature drops, and is not recommended for continuous outdoor exposure. Some of its uses are in buttons, buckles, knitting needles, adhesives, etc.

Cellulosics :—

Cellulosics are found in four different types, all thermoplastics.

(1) *Cellulose acetate* is resistant to gasoline, oil, and most household chemicals but is affected by alcohol, acetone, and alkalis. It is used extensively in industry in a wide range of products, including imitation leather, fabrics, transparent windshields, aircraft dopes, and so-called non-inflammable photographic and motion-picture films.

(2) *Cellulose acetate-butyrate* is the only cellulosic plastic recommended for outdoor use, as it withstands rough usage and sub-zero temperatures. It is resistant to most household chemicals but is adversely affected by acetone, strong alkalis, and alcohol. It is noted for its high impact strength, and finds uses in telephone housings, portable radio cases, automobile hardware, tool handles, pipes, and tubing.

(3) *Ethyl cellulose* maintains its toughness and resiliency at sub-zero temperatures and is dimensionally stable over a wide range of temperature and humidity conditions ; it is unaffected by alkalis and weak acids, but should not be subjected to cleaning fluids, oils, or solvents. This material is used for edge mouldings, wire coating, and certain electrical parts.

(4) *Cellulose nitrate* is an extremely tough material which resists most weak acids and alkalis. It discolours badly in sunlight and is the only highly inflammable plastic. While its uses have been decreasing (e.g., in motion-picture film) in the face of competition with other materials, it is still used extensively in industry. Solutions of cellulose nitrate are widely used in coatings.

Fluorohydrocarbons :—

Fluorohydrocarbons include tetrafluoroethylene and chlorotrifluoroethylene polymers and are thermoplastics having high impact strength over a wide range of temperatures. They have extremely high chemical resistance and excellent electrical properties. Fluorohydrocarbon polymers are used for making valve seats, pump diaphragms, laboratory tubing, and low-loss insulation. Up to now, their extensive use has been restricted by very high price.

Nylon :—

Nylon is a generic term applied to a family of polyamides produced by the reaction of polybasic organic acids with polyfunctional amines. It is not a trade name. The nylons are thermoplastics noted mainly for high tensile, impact, and flexural strength and for abrasion resistance. They are not affected by many ordinary chemicals, greases, and solvents, but are attacked by most mineral acids and are soluble in phenols and formic acid. Nylons are not recommended for continuous outdoor exposure unless specially stabilized. While most familiar as filaments for wearing apparel, brushes, and fishing tackle, the nylons are also used in gears, bearings, gaskets, wire insulation, etc.

Phenolics :—

Phenolics are hard, rigid, and strong thermosetting materials. They are heat- and cold-resistant, have low thermal conductivity, and are resistant to alcohol, oils, greases, and common solvents. The wide use of phenolics is due principally to their low cost and wide range of properties obtainable with different fillers. One shortcoming has been the characteristic colour of these resins, which has limited their use to dark-coloured products. They are used for such items as television and radio cabinets, handles for electrical appliances, washing-machine agitators, radio-tube bases, switch parts, and gears.

Polyesters :—

Polyesters are thermosetting materials which are combined with glass fibres or other reinforcing fillers to yield strong, durable products such as sleds, automobile bodies, luggage, pipes, interior partitions, skylights, etc.

Polythene (or polyethylene) is a semi-rigid thermoplastic with a very high flex strength even at temperatures below −70° F. In thin sections it is quite limp and flexible. Although not truly transparent, its slightly milky transparency lends itself to pigmentation. Extremely high weather resistance is obtainable through the use of properly compounded carbon black.

Polythene has extremely good dielectric properties, which have led to its widespread use in high-frequency cables. Thin films have extremely low vapour transmission, indicating its use as a vapour barrier in packaging and building construction. Its wide range of chemical resistance suits it for drum liners and tank linings, fume ducts, and various other plant uses. Its flexibility, flex strength, lack of toxicity, and resistance to chemical action have resulted in its application in the familiar " squeeze " bottle. Polythene is also used as a coating on paper, such as used for multi-wall bags. In pigmented form it is made into pipes which remain tough at low temperatures, are light in weight, do not corrode, and are easy and economical to install. Other uses are unbreakable toys, refrigerator ware, and tumblers.

Polystyrene :—

Polystyrene is a rigid thermoplastic, naturally transparent, which lends itself to a wide range of colour possibilities. The basic polymer has been modified, particularly with synthetic rubber, to increase its impact strength. It is known, from experience with many of the attractive polystyrene toys, to be somewhat brittle in unmodified form. Polystyrene has good electrical characteristics and good dimensional stability under

high humidity, but is attacked by petrol, dry-cleaning solutions, and other organic solvents. It is used in refrigerator food containers, battery cases, instrument panels, wall tile, and radio cabinets.

Silicones :—

Silicones, although not always considered as plastics, exhibit properties and behaviour often associated with thermoplastics. They are available as resins, coatings, greases, fluids, and as silicone rubber. They exhibit high heat stability and have very good dielectric properties over a wide frequency range. They are water-repellent, have good weathering characteristics, and are highly resistant to mineral acids and corrosive salt solutions. They are difficult to mould, requiring a long curing cycle, and are relatively expensive. Their major outlets are in industry, where they are used for coil forms, switch parts, induction-heating apparatus, as insulation for generator and motor coils, and in power cables.

Vinyls :—

Vinyls constitute a wide range of thermoplastic resins, many of which have their individual properties adjusted by the use of various plasticizers, extenders, and fillers. Some of the vinyl compounds have extremely high chemical resistance and low moisture absorption, while others are water-soluble. Their applications are manifold. Polyvinyl acetate is an important ingredient in many adhesives and coatings, while polyvinyl butyral is used as the interlayer in safety glass.

Polyvinyl chloride and chloride-acetate appear variously as wire insulation, shoe soles, shower curtains, rainwear, tubing, gramophone records, coated fabrics for upholstery, floor tile, gaskets, etc. Colour possibilities with some of the vinyls are virtually unlimited and they can be decorated in a variety of ways.

Epoxy Resins or Ethoxylene Resins :—

The epoxy resins, which are of the thermosetting type, have been developed quite recently. So far, their greatest use has been in the paint industry. They have also been used successfully to make adhesives which will bond together wood, glass, steel, aluminium, and other materials. These resins are still fairly expensive, thereby tending to restrict their use at present.

Conversion to Finished Products

Most plastics may be converted into finished products by one or more of the following methods :—

Moulding includes compression, transfer, injection, blow, pulp, and solvent moulding. Under the influence of temperature and pressure, plastics may be made to flow into many complex shapes by the use of suitable moulds.

Casting includes coating by spread-coating, spraying, roller-coating, dipping, and brushing. For such an application, plastics usually are used as highly plasticized pastes, organosols, solutions, and dispersions. Some are available in an unpolymerized liquid form.

Laminating includes high-pressure laminating of sheets, rods, tubes, and special shapes. The laminating resin acts as a bonding agent for a usually high filler content, or as a simple adhesive for continuous fabric or paper filler.

Low-pressure moulding is usually applied with reinforced resins, such as polyester/fibreglass. Matched moulds may be utilized, although shapes are often built upon a simple male or female mould and allowed to cure in the desired shape. Pressure is often applied by means of rubber blankets or vacuum bags.

Extrusion usually involves melting of a plastic inside a cylinder which also contains a rotating screw which forces the molten resin through a suitably shaped orifice to produce pipe, rod, belting, and a multiplicity of special shapes.

Calendering involves the squeezing of molten resin between two or more rotating rolls. These rolls may be smooth or may have various designs in the surface to produce an embossed effect on the processed sheet.

The fabricating process starts with plastic sheets, rods, tubes, etc., which may be converted to the desired shapes by machining or forming. The latter is carried out at temperatures where a thermoplastic may be readily forced into the desired shape.

Future Developments

The range of properties of plastics is greater than that of metals and much greater than that of either concrete or wood. Even so, it has been said that they behave more like wood than any other building material. They have many properties desirable in building construction, but they also have other characteristics, not inherent in ordinary building materials, and these are a disadvantage. Their modulus of elasticity is relatively low and they creep under stress. Their thermal expansion is greater than that of the older structural materials, particularly metals, and their useful temperature range is limited.

The use of plastics in the building field will therefore be stimulated by certain properties and limited by others. It is easy to make plastic products but difficult to make good ones. However, plastics will make revolutionary changes in the appearance of future buildings, if predictions of the plastics industry, foreseeing buildings covered with unbroken plastic skins in attractive colour combinations, come true. Furthermore, future buildings could have very unusual shapes, to take advantage of some of the structural properties found in plastics.

During the past five years there has been much speculation on the possible application of intense radiations to problems in the polymer fields, together with an increasing volume of research on the possibilities of the synthesis of new polymers and the improvement of the physical properties of existing polymers.

Gamma radiation offers some unique advantages as an initiating agent, in that initiation can be effected at low temperatures, where heat-sensitive monomers can be polymerized, polymerizations can be carried out in the solid state, and polymers can be made with no contamination from catalyst fragments. Recent work has shown that the physical properties of certain polymers can be markedly altered by exposure to radiation fields, and that a vulcanization type of process takes place. Future developments in this field promise to be interesting and important.

New resins which will maintain their mechanical strength under continuous exposure to certain heated liquids should further open up the tank and transportation field. Synthetic resins which will withstand temperatures of 1000° C are considered a possibility. Both at chemical-engineering and mechanical-engineering levels, research in piping should produce important results. New reinforcements, chiefly synthetic fibres, may provide specialized materials for applications not practical at present.

Standardization in all the above-mentioned fields is expected to provide sound engineering design data which will increase the acceptance of these materials. The lack of precise data has to-date tended to limit the use of plastics by engineers. However, a considerable increase in the use of reinforced plastics for metal tooling is a certainty.

Much criticism has been aimed at the plastics industry because of the " backyard " nature of many of its conversion operations. However, the suppliers of materials and the industry societies have exerted a stabilizing influence. This, coupled with a sincere effort on the part of many converters, has led to a sharp upgrading of the industry's status. The next few years are likely to be the most fruitful with regard to developments of materials, technological progress, and widening of applications.

Water Injection into Internal Combustion Engines

By C. F. KETTLEBOROUGH and E. E. MILKINS. (From *Commonwealth Engineer*, Vol. 42, No. 8, March 1, 1955, pp. 303-308, 7 illustrations.)

In this article the results of experiments on the effect of water injection into a petrol engine are given, and show that reduced detonation and carbon formation, as well as an increase in power output, can be obtained.

ALTHOUGH water injection into internal combustion engines is more than forty years old, keen interest in this subject was taken during World War II only for take-off and power boost of combat aircraft. Since 1945, however, the general public has shown increasing interest in applying water injection to automobiles, to increase efficiency and/or power output.

This article reports some experiments on the effect of water injected into a petrol engine.

EQUIPMENT

The engine used was a Ricardo E.6-type variable-compression engine. This unit is a single-cylinder poppet-valve four-stroke engine of 507 cc capacity, with valves set vertically in the head and operated by an overhead camshaft. The bore and stroke are 3 in. and 4¾ in. respectively. The engine is a rigid, compact structure and well able to withstand the higher maximum cylinder pressures associated with operations at high compression ratios.

Compression ratio can be varied from 4·5:1 to 20:1. The outer surface of the cylinder jacket slides in a cast-iron guide, and the lower portion is threaded to accommodate a nut, rotation of which, by a worm wheel, raises and lowers the cylinder relative to the crankshaft. Thus, it is possible to vary the compression ratio while the engine is running.

The valves are operated through rocker arms by an overhead camshaft, which also provides a drive for the magneto, the timing of which can be varied whilst the engine is running. The vertical telescopic shaft which transfers the drive from the crankshaft to the camshaft through two pairs of bevel wheels, is in two parts, keyed together. The normal speed range is from 1000 to 3000 rpm.

The lubricating-oil system is of the wet-sump type incorporating a full-flow filter, the oil being delivered by an electrically driven pump to the main and big-end bearings. The camshaft is supplied from the same pump through a separate oil feed, rate of flow being regulated by two holes in the camshaft journal. Each cam is fed through a hole drilled in its face and receives a supply of oil twice per camshaft revolution. The oil is kept at the desired temperature by an externally mounted cooler and an electric heater fitted in the crankcase.

The engine is equipped with a Solex carburettor fitted with a choke, 27 mm in diameter, and a variable main jet, consisting of a taper-needle valve, permitting the mixture to be varied as required during tests. Fuel flow is measured by noting the time taken for 70 cc of fuel to be consumed by the engine. Water consumption is measured by noting the time to inject 20 or 30 cc. Air consumption is measured by the usual air-box method, using a calibrated orifice plate.

The combustion chamber is cylindrical in shape, being bounded by the flat surfaces of the cylinder head and piston. This ensures that the chamber retains the same general form when compression ratio varies. The sparking plug is situated at the side of the combustion chamber, between the valves. A similar hole on the other side of the combustion chamber enables the position of the sparking plug to be changed, placing it near either the inlet or exhaust valve.

In these tests this second hole was used for a capacity-type pressure cell, which, through suitable electronic circuits, produced on a cathode-ray oscilloscope an indicator diagram which can be suitably photographed.

The fuel used was standard commercial petrol, having an octane number of 71·3, with 1·03 ml of tetra-ethyl lead per gallon and a net calorific value of 18,900 BTU/lb.

The water-injector unit was situated between the butterfly valve and the engine inlet valve. Running the engine causes in the inlet manifold a pressure drop which is transmitted through the injector nozzle to one side of a diaphragm, loaded by atmospheric pressure on the other side. This reduction in pressure causes a valve to open for the admission of water. Upstream of this valve is a manually operated needle valve. The quantity of water injected can be manually controlled by the needle valve and, once this has been set, throughput is controlled by the manifold-pressure-operated valve. Under very low manifold pressures an auxiliary spring-loaded valve causes water flow to be cut off immediately; at these lower manifold pressures detonation never occurs.

EXPERIMENTAL RESULTS

Compression Ratio of 5·5 :—

Tests of fuel consumption at half throttle, with a compression ratio of 5·5, were carried out for the following three cases :—

(1) Without water.
(2) 0·70 lb of water per pound of fuel at the optimum jet setting of approximately 0·82.
(3) 1·9 lb of water per pound of fuel at the same jet setting as in case (2).

The jet setting is an arbitrary scale, the jet being entirely closed at a setting of zero. With no water injected, the most economical consumption was 0·56 lb/bhp-hr, corresponding to an overall efficiency of 24·1%, based on the lower calorific value of the fuel.

The effect of water injection was to increase the specific fuel consumption at the jet setting corresponding to maximum economy to 0·59 and 0·69 lb/bhp-hr for cases (2) and (3) above, respectively, corresponding to efficiencies of 22·8 and 19·5%. The maximum output of 7·45 bhp without water was reduced by the addition of water to 7·36 bhp (case (2)) and to 6·81 bhp (case (3)).

The engine operated satisfactorily without any water injection, and it was clearly established that the addition of water in these circumstances decreases both efficiency and power output, although the effect is not marked until a large quantity of water is injected.

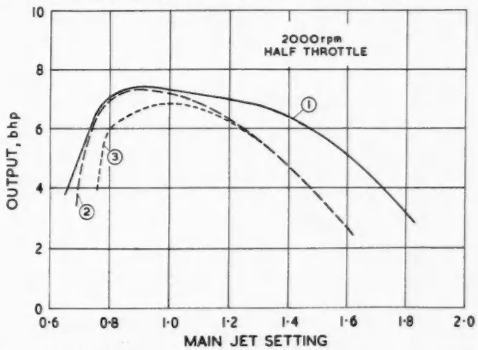


Fig. 1. Variation in power output with main-jet setting, with a compression ratio of 5·5.

(1) No water added.
(2) 0·70 lb of water per pound of fuel at the optimum jet setting of 0·82 approximately.
(3) 1·9 lb of water per pound of fuel at the same jet setting as in (2).

Fig. 1 shows the variation in power output with main-jet setting for the above three cases, while Fig. 2 shows water/fuel ratio plotted against jet setting. The injector remained at a constant setting for each loop; hence, as the jet setting is increased, signifying an increase in orifice size and hence an increase in fuel flow, the ratio is decreased. The engine operated satisfactorily with very large rates of flow of water.

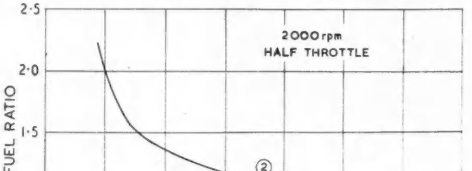


Fig. 2. **Water/fuel ratio plotted against main-jet setting, with a compression ratio of 5·5.**

(1) 0·70 lb of water per pound of fuel at the optimum jet setting of 0·82 approximately.
(2) 1·9 lb of water per pound of fuel at the same jet setting as in (1).

The water injected passes out of the exhaust as steam; the heat required to evaporate the water is drawn from the heat released during the combustion of fuel. Since more heat is rejected with water injection, both the efficiency and the power developed decrease. Hence, there is no advantage to be gained if the engine operates satisfactorily without water.

Optimum Compression Ratio without Water :—

The compression ratio was increased in increments of 0·1 to ascertain what may be called the highest useful compression ratio without water injection. Detonation was detected by ear and/or high-frequency pressure fluctuation on a C.R.O. indicator diagram.

The value of the highest useful compression ratio was found to be 6·2. Above this value detonation became more pronounced and, as the compression ratio was further raised, it became more and more difficult to operate satisfactorily under varying conditions of load and jet setting. Fig. 3 shows the fuel-consumption loop obtained at this compression ratio. The fuel consumption has decreased slightly to 0·55 lb/bhp-hr (24·5% efficiency) and maximum output is 7·5 bhp.

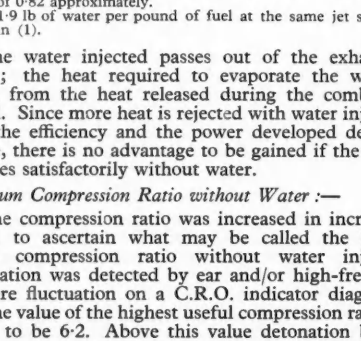


Fig. 3. **Specific fuel consumption without water injection, with a compression ratio of 6·2.**

A maximum compression ratio of 6·2 is low for the average spark-ignition engine. However, the engine was not in first-class condition; even when overhauled the engine was prone to detonation. Since its last overhaul, the lubrication to the cams had failed and, before this had been rectified, wear had taken place, thus altering the whole valve-timing sequence. These tests were carried out to ascertain what improvements could be made to the performance of an engine in need of an overhaul.

Further Increases in Compression Ratio :—

Tests were carried out with a compression ratio of 7·0 and two rates of water flow, *viz.* :—

(1) The minimum flow required to prevent detonation at approximately the correct mixture, with a jet setting of 0·83.
(2) A much larger flow of water, compared with (1).

The results showed that fuel consumption was further decreased to 0·52 lb/bhp-hr (26·2% efficiency) and that power was increased to 8·26 bhp. The amount of water required at the correct mixture was 0·81 lb of water per pound of fuel. Approximately doubling the quantity of water served merely to reduce maximum power very slightly and to increase specific fuel consumption slightly.

The maximum compression ratio at which the engine would operate in its present condition was slightly greater than 7·55. This ratio was taken as the maximum permissible. The water requirement at the correct jet setting of 1·0 was 1·65 lb of water per pound of fuel.

The method of adjusting the water-injector control was to run the engine at 2000 rpm at a jet setting of 1·0 (approximately correct) and to unscrew the needle valve controlling the water flow until detonation ceased completely. The results showed a further decrease in specific fuel consumption to 0·5 lb/bhp-hr (27% efficiency) and an increase in power output to 9·02 bhp.

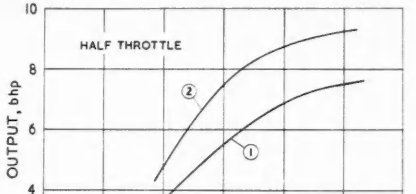


Fig. 4. **Variation in power output with speed.**
(1) Without water injection; compression ratio 6·2.
(2) With water injection; compression ratio 7·55.

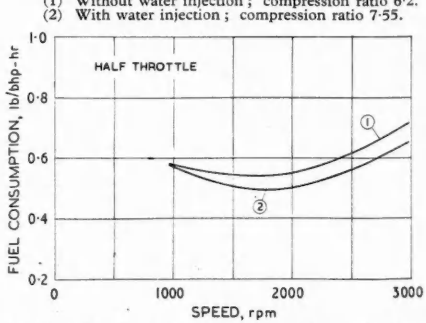


Fig. 5. **Variation in fuel consumption with speed, with the jet set for maximum economy.**
(1) Without water injection; compression ratio 6·2.
(2) With water injection; compression ratio 7·55.

At a compression ratio above 7·55 the running of the engine was temperamental. At times it would run satisfactorily for some minutes and then drop off quickly in speed. For limited periods it has been possible to operate at a compression ratio of 9. However, above a compression ratio of 7 55 "running on" was very prevalent.

Figs. 4 and 5 show variations in power output and fuel consumption respectively with speed, for compression ratios of 6 2 (without water) and 7 55 (with water), with the main jet set at approximately the correct mixture determined from the fuel-consumption loops. Power output has increased over the whole speed range, whilst specific fuel consumption has decreased.

The amount of water required was about 1·6 lb per pound of fuel. This is somewhat excessive, if it has to be carried. However, if a small amount of detonation can be tolerated—and this is usually accepted—the engine operates with about 0·5 lb of water per pound of fuel.

CONCLUSIONS

Raising the compression ratio from 6·2 to 7·55 increases efficiency from 24·5% to 27·1%. The maximum power output increases from 7·5 to 9·02 bhp, i.e., an increase of 20·3%—a not inconsiderable amount.

For any given compression ratio there is a drop in thermal efficiency and power as the quantity of water injected is increased.

The amount of water required per pound of fuel is excessive, but it should be noted that the tests were carried out to ascertain what improvements, if any, could be obtained on an engine requiring some attention. Moreover, the minimum amount of water used at a compression ratio of 7·55 eliminates detonation completely and the quantity of water used could be cut down to about 0·5 lb per pound of fuel, if a small amount of detonation could be tolerated.

Space and weight requirements for carrying water may be large. Care must also be taken to ensure that freezing of the water does not take place. Very little effect on crankcase-oil dilution has been noted.

After some months of running, the engine was stripped for inspection. It was found that the piston, cylinder head, and valves were almost entirely free from carbon. If for no other reason, the use of water to prevent carbon formation is to be recommended.

The engine is to be overhauled and further tests are to be carried out with water and alcohol injection and with high compression-ratio sparking plugs.

ITALY

Electrostrictive Vibrations of a Hollow Cylinder of Barium Titanate

By M. FEDERICI. (From *Alta Frequenza*, Vol. 24, No. 1, February 1955, pp. 5-11, 3 illustrations.)

THE possibilities of tubes of barium titanate used as electrostrictive vibration generators are of particular interest. Unlike transducers made of laminated nickel or quartz, a hollow cylinder of barium titanate can radiate radially as well as longitudinally. This makes it possible to compare the mechanical and electrostrictive properties of the material in both directions. For longitudinal vibrations the mechanical constants are the same as for small plates vibrating longitudinally; for radial vibrations the constants can be calculated in a similar manner, taking account of the different mode of vibration.

The strain or relative deformation x of a tube of barium titanate is in conformity with the relation

$$x = q\,(D/4\,\pi)^2 \quad \ldots \quad \ldots \quad (1)$$

where q is an electrostrictive constant and D is the electric displacement. When the residual continuous electrical polarization is very high, relative to the applied alternating electric field V/s, then, for a cylindrical tube of wall thickness s,

$$x = Vd/s \quad \ldots \quad \ldots \quad (2)$$

where d is an electrostrictive constant depending on the residual polarization, while V is the applied voltage. To examine high-frequency phenomena, the mechanical stress σ due to the electrostrictive effect can be expressed as

$$\sigma = E\,Vd/s \quad \ldots \quad \ldots \quad (3)$$

where E is the modulus of elasticity.

In the case of radial vibrations, the radial stress p to which the tube is subjected is a component due to the tangential stress σ. For a thin tube with a mean radius r, a length l, and a wall thickness s, the radial stress is

$$p = \sigma\,s/r \quad \ldots \quad \ldots \quad (4)$$

The total force causing radial deformation of the tube is therefore

$$F_r = 2\,\pi\,r\,l \times \sigma\,s/r = 2\,\pi\,l\,s\,\sigma \quad \ldots \quad (5)$$

and this force can be expressed as a function of the applied voltage V by means of eq. (3) as

$$F_r = 2\,\pi\,l\,s\,E\,Vd/s = 2\,\pi\,l\,E\,Vd \quad \ldots \quad (6)$$

The radial displacement is

$$\xi_r = F_r/j\,\omega\,Z_m = 2\,\pi\,l\,E\,Vd/(j\,\omega\,Z_m) \quad \ldots \quad (7)$$

where Z_m is the mechanical impedance of the tube for radial vibration. The impedance, $Z_m = R_{mr} + j\,(M_r\omega - S_r/\omega)$, can easily be calculated. The vibrating mass M_r is equal to the static mass, since all the points vibrate with the same vibration velocity. Therefore, with the notation r_o = mean radius (Fig. 1) and ρ = mass-density,

$$M_r = 2\,\pi\,r_o\,s\,l\,\rho \quad \ldots \quad \ldots \quad (8)$$

The stiffness S_r can be calculated by taking account of the fact that the resonant phase velocity ω_{ro} must be such as to make the mean perimeter (Fig. 1) equal to one wavelength λ. Hence (with c = velocity of propagation, so that $\omega_{ro} = 2\,\pi\,c/\lambda = c/r_o$),

$$S_r = M_r\,\omega_{ro}^2 = M_r\,c^2/r_o^2 = 2\,\pi\,r_o\,s\,l\,c^2\,\rho/r_o^2 = 2\,\pi\,s\,l\,E/r_o \quad \ldots \quad \ldots \quad (9)$$

The mechanical damping, or resistance, R_{mr} (disregarding any concentrated acoustic loads) can be taken as being proportional to the mass, so that, by introducing a constant α,

$$R_{mr} = \alpha\,M_r = 2\,\pi\,\alpha\,r_o\,s\,l\,\rho \quad \ldots \quad \ldots \quad (10)$$

The strain due to radial deformation thus becomes

$$x = \xi_r/r = 2\,\pi\,l\,E\,Vd/(j\,\omega\,Z_m\,r) \quad \ldots \quad (11)$$

The polarization P due to the electrostrictive effect will be proportional to x, with the proportionality constant Ed. The current density u (per unit area) due to the deformation is

$$u = j\,\omega\,x\,Ed = 2\,\pi\,l\,(Ed)^2\,V/Z_m r \quad \ldots \quad (12)$$

The total current due to the electrostrictive effect is

$$I_p = u \times 2\,\pi\,r\,l = (2\,\pi\,l\,d\,E)^2\,V\,r/Z_m r = V/(A_r^2\,Z_m) \quad (13)$$

where $A_r = 1/(2\,\pi\,l\,Ed)$. The dielectric current is

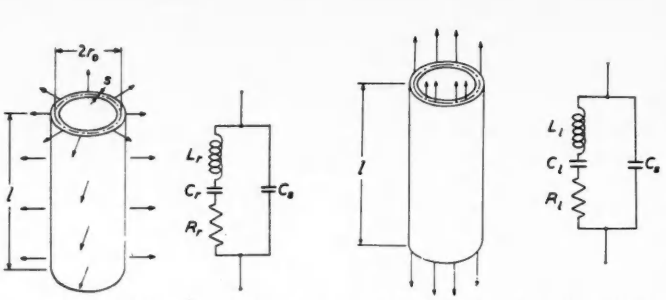


Fig. 1. **Radial** ((left) **and longitudinal** (right) **modes of vibration of a hollow cylinder of barium titanate, and their equivalent electrical circuits.**

The coupling coefficient is obtained as the ratio of the mechanical strain energy divided by the corresponding electrical energy. On a basis of one unit volume,

$$K^2 = (\sigma i/2)/(C V^2/2) = E\,Vd \times Vd/(\varepsilon V^2/4\pi) = 4\pi E d^2/\varepsilon \quad \ldots \quad (21)$$

where i is the variation in length of a small cube of unit volume, obtained from eq. (2). This coupling coefficient can be calculated by means of the difference

$$\Delta\omega_e = \omega_e - \omega_o$$

i.e., the difference between the mechanical resonant phase velocity ω_o (equality between mass reactance and elasticity reactance in the mechanical vibration) and the electrical antiresonant phase velocity ω_e of the cylinder, which corresponds to resonance in parallel of the two branches of the electrical circuit ($\omega_e = 1/\sqrt{L_r C_r}$).

For longitudinal vibrations ($\Delta\omega_e = \Delta\omega_l$) it has been proved[2] that, with adequate approximation,

$$K_l^2 = (\pi^2/8) \times (2\,\Delta\omega_l/\omega_{lo}) \quad \ldots \quad (22)$$

From the equivalent diagram, it will be found that $C_r/C_s = 2\,\Delta\omega_r/\omega_{ro}$ in the case of radial vibrations. As, from eqs. (17) and (21),

$$C_r/C_s = 4\pi E d^2/\varepsilon = K^2 \quad \ldots \quad \ldots \quad (23)$$

then

$$K_r^2 = 2\,\Delta\omega_r/\omega_{ro} \quad \ldots \quad \ldots \quad (24)$$

where $\Delta\omega_r$ and ω_{ro} have the same meanings as previously, with reference, however, to radial vibrations.

An experimental investigation was made of a hollow cylinder of barium titanate with $s = 0{\cdot}3$ cm, $l = 3{\cdot}8$ cm, $r_o = 1{\cdot}75$ cm; this tube had a relative dielectric constant of 1150 at ambient temperature, and a static capacitance of 14,000 $\mu\mu$F.

It was found that the longitudinal resonant frequency had a value of 60,800 cps; the difference Δf_l between the frequencies in series and in parallel was 840 cps, and therefore $K_l = 0{\cdot}186$; the equivalent constants are $C_l = 480$ $\mu\mu$F, $L_l = 0{\cdot}0554$ henry, and $R_l = 25$ ohms. The radial resonant frequency was 38,750 cps. The ratio between the two is therefore 1·56, whereas it should be 1·48 according to the dimensions. The material has a specific gravity of 5·4. The radial coupling coefficient was obtained as $K_r = 0{\cdot}108$. The equivalent radial constants are $C_r = 138$ $\mu\mu$F, $L_r = 0{\cdot}123$ henry, and $R_r = 115$ ohms.

$$I_d = j\,\omega\,VC_s \quad \ldots \quad \ldots \quad (14)$$

where C_s (Fig. 1) is the static capacitance, given by the formula

$$C_s = \varepsilon \times 2\pi r\,l/4\pi s = \varepsilon r\,l/2\,s \quad \ldots \quad (15)$$

ε being the dielectric constant.

The total current is $I_t = I_p + I_d$, and therefore the electrical impedance opposing the voltage V is $Z_e = V/I_t$ or

$$Z_e = \frac{1}{j\,\omega\,C_s + \dfrac{1}{A_r^2\,Z_m}} = \frac{1}{j\,\omega\,C_s + \dfrac{1}{R_e + j\,[\omega\,L_e - (1/\omega C_e)]}} \quad \ldots \quad (16)$$

For the case of Fig. 1, the electrical constants R_e, L_e, and C_e are therefore:

$$L_e = L_r = r_o\,s\,\rho/(2\pi\,l\,E^2\,d^2);$$
$$C_e = C_r = 2\pi\,l\,r_o\,E\,d^2/s;$$
$$\text{and } R_e = R_r = \alpha\,r_o\,s\rho/(2\pi\,l\,E^2\,d^2); \quad \ldots \quad (17)$$

so that, with $C_s = \varepsilon\,r_o\,l/2\,s$, $C_r/C_s = 4\pi\,E\,d^2/\varepsilon$.

In the case of longitudinal vibrations (Fig. 1), the electro-mechanical conversion ratio A_l is similarly obtained by means of the expression for the electric current due to axial deformation.[1] The corresponding results for the square of the conversion ratio, the vibrating mass, and the stiffness are

$$A_l^2 = 1/(6\pi^2\,r_o^2\,E^2\,d^2);\quad M_l = \pi\,r_o\,s\,l\,\rho;$$
$$\text{and } S_l = \pi^3\,r_o\,s\,E/l; \quad \ldots \quad \ldots \quad \ldots \quad (18)$$

while the resonant phase velocity is obtained as

$$\omega_{lo} = \sqrt{S_l/M_l} = (l/\pi)\,\sqrt{E/\rho} \quad \ldots \quad \ldots \quad (19)$$

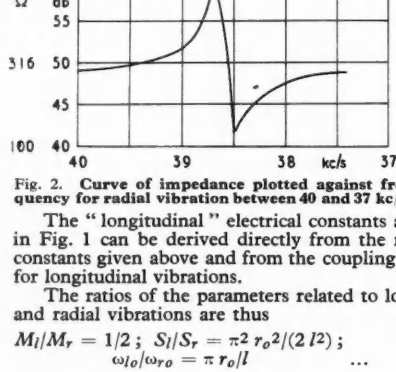


Fig. 2. **Curve of impedance plotted against frequency for radial vibration between 40 and 37 kc/s.**

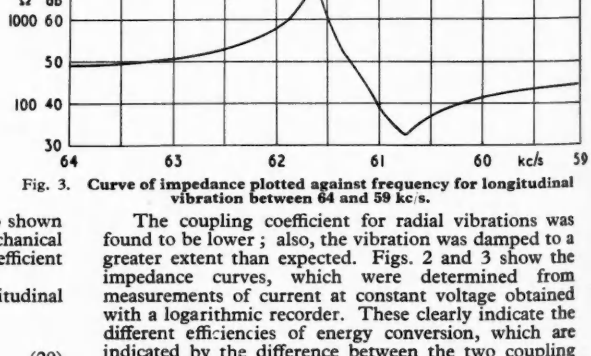


Fig. 3. **Curve of impedance plotted against frequency for longitudinal vibration between 64 and 59 kc/s.**

The "longitudinal" electrical constants also shown in Fig. 1 can be derived directly from the mechanical constants given above and from the coupling coefficient for longitudinal vibrations.

The ratios of the parameters related to longitudinal and radial vibrations are thus

$$M_l/M_r = 1/2;\quad S_l/S_r = \pi^2\,r_o^2/(2\,l^2);$$
$$\omega_{lo}/\omega_{ro} = \pi\,r_o/l \quad \ldots \quad \ldots \quad (20)$$

The coupling coefficient for radial vibrations was found to be lower; also, the vibration was damped to a greater extent than expected. Figs. 2 and 3 show the impedance curves, which were determined from measurements of current at constant voltage obtained with a logarithmic recorder. These clearly indicate the different efficiencies of energy conversion, which are indicated by the difference between the two coupling coefficients.

[1] W. G. Cady: Piezoelectricity. McGraw-Hill Book Co., 1946, p. 297.

[2] W. P. Mason: Piezoelectric crystals and their application to ultrasonics. D. Van Nostrand, 1950, p. 66.

Isothermal Hardening of Alloy Tool Steels

By Yu. A. Geller. From *Stanki i Instrument*, No. 10, October 1954, pp. 16-20, 8 illustrations.)

It has been shown by Anosov and Chernov[1,2] that the holding of an austenitized steel at temperatures around 200° C, with subsequent air cooling, improves mechanical properties in comparison with those obtained as a result of direct quenching in oil or in water. Treatment of this type was applied from about 1830 onwards in a number of steelworks in the Urals for some tools and components of small section made of steels with a carbon content greater than 0·5%.

The transformations taking place in the steel as a result of such holding were later studied by Steinberg,[3] who showed in particular that retardation of cooling below 200° C enables a larger amount of residual austenite to be retained and reduces physical deformation on hardening.

Interrupted hardening with short holding (2 to 3 min) near the temperature of the start of martensitic transformation (M_s point) received wide application, from about 1930 onwards, for carbon and alloy steel tools[4] with the object of reducing deformation and stresses. The effect, however, of prolonged hardening around the M_s point upon the properties of tempered tool steel was not still not fully studied.

In 1938, Gulyaev and Belova[5] investigated the transformations and changes in dimensions of specimens, 5 mm in diameter, of U.12 and KhG steels (see Table I), and found that an increase in holding time at 200° C to 30 min, with subsequent cooling in air, increasing the amount of retained austenite, also reduces the change in dimensions of the specimens. However, in order to obtain satisfactory hardness, it was found necessary to use a hardening temperature 30 to 40° C higher than that normally employed for hardening by conventional methods. It was then established that variations in the length of holding around M_s affect the amount of deformation and the mechanical properties of tool steel in various ways.

Table I. Composition of Russian Tool Steels*

Type	Composition, %				
	C	Mn	Si	Cr	W
U.12	1·1 –1·25	0·15–0·25	0·30	0·2	—
KhG	1·3 –1·5	0·45–0·70	0·35	1·3 –1·6	—
Kh(ShKh15)	0·95–1·10	< 0·4	< 0·35	1·3 –1·6	—
9KhS	0·85–0·95	0·3 –0·6	1·2 –1·6	0·95–1·25	—
9KhVG	0·85–0·95	0·8 –1·1	0·15–0·35	0·5 –0·8	0·5–0·8

* Compiled from data in *Materials and Methods*, U.S.A., August, 1953. Editor, E.D.

Oding,[6] after studying the deformation of specimens of Kh(ShKh15) and KhG steels in relation to the length of holding at 250° C, found that an increase in holding time of 30 to 90 sec reduces distortion, but that more prolonged holding again increases distortion.

Rachstadt and Shadkin[7] studied the effect of holding at 150° and 170° C for periods of 10 min and 3, 15, 25, 50, and 90 hr on the amount of retained austenite, the specific electrical resistance, and the change in diameter of specimens of 9KhS steel. They also established the change in diameter of hardened specimens and the physical properties of the steel. Increasing holding time from 10 min to 3 hr resulted in a sharp increase in the diameter, whilst raising the period to 15 hr gave a reduction in the diameter in relation to its dimensions prior to holding; then, a further increase in the period to 90 hr again led to increased diameter. The amount of residual austenite grew with an increase in holding time up to 25 to 30 hr, but fell as a result of a further increase.

An increase in holding time up to 1 hr at 250 to 300° C brought about a sharp increase in strength; further prolongation of holding lowered the strength, but still further prolongation again raised it. A similar pattern for alteration in strength was obtained when the steel was held at 150° C. However, the hardness of Kh steel fell as a result of isothermal holding to 58 to 59 R_c. This hardness was obtained with specimens 8 mm in diameter and with a hardening temperature of 940° C. There is no doubt that an increase in the cross-section of the tools and a reduction in hardening temperature to a level which would not cause significant grain growth (840 to 850° C) would also greatly reduce hardness.

Prosvirin and Entin[8] studied the effect of holding at 150° C on the magnetic properties and the impact

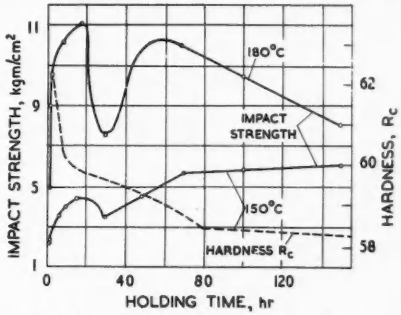


Fig. 1. **Variation of hardness and impact strength of unnotched specimens of hardened Kh(ShKh15) steel with isothermal holding time.**

strength of unnotched specimens of Kh(ShKh15) steel. They obtained a quite considerable rise in strength (Fig. 1) as a result of holding for 15 hr. A further increase in holding to 20 to 30 hr lowered the strength, but an increase to 45 hr again improved it. The hardness of the steel was in this case about 59 R_c.

There is still no generally accepted opinion as to the causes bringing about such a change in the properties of hardened steel. Prosvirin and Entin are of the opinion that the change in strength results from coagulation of the carbide particles liberated from the solid solution during holding. A drop in strength indicates the presence of carbides of varying degrees of dispersion and their non-uniform distribution in the structure. Carbide coagulation, occurring with more prolonged holding, improves the strength; however, this process is accompanied by a further release of carbide particles, the non-uniform coagulation of which at certain stages of holding causes a new decrease in strength.

Thus, holding around M_s (assuming that the length of time chosen is correct) makes it possible to obtain considerably higher strength and smaller changes in volume in comparison with those achieved by air hardening or interrupted hardening with short holding at around M_s. However, an obstacle to employing such hardening in production conditions is the lowering of the hardness (for Kh(ShKh15) steel) and the necessity of long holding for many hours around M_s.

Investigations carried out by Geller and Schreiber[9] into the hardening characteristics of tool steels of various types showed that Kh steel, using specimens 200 mm in diameter, falls in hardness to about 58 R_c as a result even of short holding (15 to 30 min) at 150° C. KhG steel has slightly better characteristics, but only in cases where holding temperature does not exceed 170° C. At the same time, the more highly alloyed 9KhS steel has great stability of austenite prior to cooling and as a result maintains a high degree of hardness (60 to 63 R_c) after long holding and with variations in temperature

around M_s within the sufficiently wide limits possible in production. With an increase in holding time the hardness of this steel falls a little. Hardness increases somewhat if holding is effected, not in a molten mixture of KNO_3 and $NaNO_2$, but in an alkaline medium with a severe quenching effect. An increase in the hardening temperature of 9KhS steel from 870-875 to 880-885° C, which still does not cause any special grain growth, also makes it possible to achieve greater hardness.

For these reasons, investigations were made regarding the effect of hardening with isothermal holding around M_s on the transformations, structure, and basic properties of 9KhS steel, but under conditions where the holding time was shorter and adaptable to production-line needs, lasting from 5 min to from 2 to 3 hr. Subsequent cooling was in air. The M_s temperature for 9KhS steel, hardened from 870 to 880° C, is about 170° C.

The investigations showed that holding around M_s brings about a number of changes, i.e., (*a*) it increases the amount of residual austenite in the structure of the hardened steel, (*b*) it favours the release of part of the carbides from the solid solution, and (*c*) it causes an isothermal martensitic transformation.

Holding for a period of 2 to 3 hr has a maximum effect on the increase in the amount of residual austenite. The magnetic saturation of hardened steel diminishes considerably (Fig. 2) as holding time increases up to 180 min at 160° C. Holding at a higher temperature, but for shorter periods (60 min at 180° C and 30 min at 200° C) causes an even greater drop in magnetic saturation. Holding at 180 to 200° C for 180 min has hardly any effect and slightly raises magnetic saturation. However, even after holding for 180 min at 180 to 200° C, it remains smaller than in steel quenched in oil or a salt bath at 160 to 200° C with a short holding time (up to from 10 to 15 min). Such a great drop in magnetic saturation is a result of the growth in the amount of residual austenite.

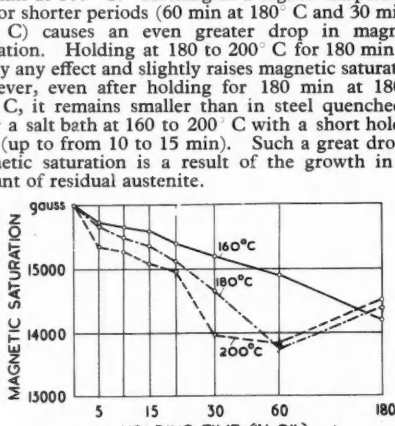


Fig. 2. **Variation of magnetic saturation of 9KhS steel with temperature and isothermal holding time in hardening.**

Thus, isothermal holding around M_s arrests the martensitic transformation on subsequent cooling and brings about stabilization of austenite. Even short holding (5 to 10 min) at 150° C is of no effect in stabilizing austenite. However, this process is more pronounced when holding is increased to between 30 and 60 min or when the holding temperature is raised to between 180 and 200° C. It is characteristic that raising the holding time to longer than 30-60 min at 180-200° C lessens the effect of stabilization, whereas a similar increase in holding at a lower temperature (160° C) does not reduce this effect.

At the time of holding at M_s there also occurs a release of α-phase (including troostite needles). At 200° C the formation of α-phase is preceded by an incubation period lasting from 7 to 8 min. When holding is prolonged to 30 min, there is a slight release of α-phase, which, on further holding for from 2 to 3 hr, takes place more intensively than at lower temperatures. However, the amount of α-phase forming even under these conditions of holding is small and is only just discernible by micro-examination.

The electrical resistivity of hardened steel falls with an increase in holding time. However, relatively short periods (15 to 30 min) at 160 to 200° C do not bring about any great reduction in electrical resistivity, whereas prolonged holding reduces it noticeably.

Changes in the specific electrical resistivity do not enable conclusions to be drawn directly as to the transformations taking place during isothermal holding, and in particular to release of carbides, since this characteristic is the result of the differing electrical resistivity of residual austenite and martensite at various stages of dissociation. It should, however, be taken into account that subsequent tempering lowers electrical resistivity. Provided that the tempering does not cause dissociation of the residual austenite, then the reduction in electrical resistivity may be the result of one process only, i.e., the release of carbide particles from martensite. If, in isothermal holding, there were no release of carbides and the solutions had a uniform carbon content, as in steel cooled in oil and in steel subjected to isothermal holding of varying duration, then the electrical resistivity after tempering would in both cases be approximately identical.

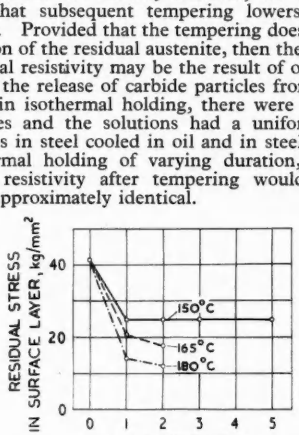


Fig. 3. **Variation of residual stresses in the surface layer of a specimen of Kh(ShKh15) steel (hardened at 850° C) with holding time.**

Isothermal holding gives stabilization of austenite and increases the amount of residual austenite. An increase in the amount of residual austenite, not accompanied by grain growth, must have a beneficial effect on the mechanical properties of hardened steel and, in addition, must reduce the tool deformation brought about by hardening.

Mechanical Properties

A decline in the part played by the contribution of austenite to martensitic transformation reduces the stresses arising during hardening. Holding around M_s, with subsequent slow cooling in air, also reduces thermal stresses. This is confirmed by tests carried out to determine mechanical properties. Short holding up to 5 min only slightly improves mechanical properties in comparison with those obtained by oil-quenching. At the same time an increase in holding time at 160° C to 30 to 60 min considerably raises strength. After tempering at 180° C the strength of such a steel is approximately 50% higher than in an oil-quenched steel. Increasing holding time to 180 min at 160° C apparently does not improve strength owing to the non-uniform coagulation of the carbides released during holding. Even in this case, however, the mechanical properties remain higher than in the same steel quenched in oil or in a salt bath and held for the normal period (up to from 3 to 5 min).

Holding at 180° to 200° C has the same effect, with the difference that improved mechanical properties are obtained as a result of shorter holding times (30 min); more lengthy holding appears to be less effective.

A much greater increase in holding time (up to between 2 and 3 hr) around M_s reduces hardness. This is caused by an increase in the amount of residual austenite, a reduction in carbon content of the martensite, and coagulation of the liberated carbide particles.

After holding for 30 to 60 min the hardness of 9KhS steel falls to 61 R_c, and after holding for 3 hr to between 59 and 60 R_c.

Greater hardness (62 R_c) may be obtained by raising the hardening temperature of 9KhS steel to 880-885° C, lowering the temperature of isothermal holding to 150-160° C, and by holding in alkaline media (but not in potassium nitrate). Subsequent tempering does not have the same effect on the mechanical properties of the steel held for different periods around M_s after hardening. Tempering raises the mechanical properties as a result of the release and coagulation of carbides and relieving of part of the residual stresses caused by hardening.

Since tempering reduces only a portion of the stresses (Fig. 3), the mechanical properties of a steel held for a considerable period around M_s remain higher in the tempered state than in a steel hardened by oil-quenching or short holding (2 to 5 min) at 150-200 °C. This, in turn, makes it possible to fix a lower tempering temperature (150-160° C) after hardening with long holding around M_s, and as a result to preserve in the tempered steel nearly all the hardness present after quenching.

At the same time, tempering at higher temperatures (300-400° C), thus reducing the greater part of the stresses, lessens this difference in mechanical properties. Steel hardened with isothermal holding around M_s has, after tempering at 300-400° C, more or less the same mechanical properties as a steel hardened or oil-quenched, or held for a short time around 150-200° C and tempered at the same temperature.

Deformation on Hardening

An increase in the amount of austenite and improvement in the mechanical properties in the hardened state reduce the change in dimensions and deformation of tools occurring on hardening. This reduction is seen after holding for a short time in a hot medium, but is far greater as a result of longer holding around M_s (Fig. 4). After holding for 60 min at 160° C, and 30 min at 180-200° C, the change in dimensions and deformation of specimens are virtually at their minimum. Deformation of specimens falls in proportion to the growth in the amount of residual austenite.

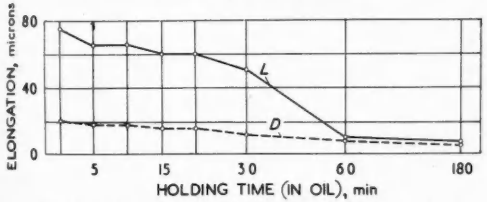


Fig. 4. **Variations in length L and diameter D of specimens of 9KhS steel (L = 50 mm; D = 15 mm) with isothermal holding at 160° C.**

Minimum deformation is obtained as a result of holding, after which the steel has its greatest strength and resistance to plastic deformation. Thus, isothermal holding makes it possible to reduce to a large extent the grinding and polishing of tools which are of complex form or which have large length-diameter ratios.

Conclusions

(1) The holding of hardened steel for 30 to 60 min at 150-200° C greatly improves its properties.

An alloy tool steel with high stability of precooled austenite obtains great hardness in the hardened state, not only on oil-quenching or on short holding (2 to 5 min) in a salt bath at 150-200° C (interrupted hardening), but also after longer holding at 150-200° C (isothermal hardening).

Of the alloy tool steels used at the present time, 9KhS and KhVG are found to possess this property.

(2) Results of investigations make it possible to select cooling conditions for hardening and to determine the range of application of interrupted and isothermal hardening for tools made of 9KhS steel.

(3) Interrupted hardening, linked with holding for a short period (2 to 5 min) in hot media at 150 to 200° C, and subsequent air cooling do not bring about any great modifications in the structure, though they do make for a small rise in the residual austenite on account of the slowness of passing through the range of martensite transformation. Increasing holding at 150-200° C up to 10-15 min raises the amount of residual austenite, thus lowering the residual stresses. The use of interrupted hardening enables greater mechanical properties to be obtained in the hardened state and reduces the dimensions of the tool in comparison with those obtained by standard hardening with oil-quenching. After interrupted hardening, the steel has the same hardness as after standard hardening.

(4) Isothermal hardening involves a longer holding period around M_s, as a result of which there is a partial retardation of the austenite transformation on further cooling. Thus, isothermal hardening alters the structure of hardened steel in comparison with that obtained after standard and interrupted hardening.

It is recommended that the holding time at 150-200° C be chosen within the limits of 30 to 60 min. In this case isothermal hardening raises to a large extent the amount of residual austenite and will barely bring about the troostite transformation.

Isothermal hardening is considerably more effective in reducing residual stresses than interrupted hardening; it improves mechanical properties, both in the hardened and the tempered state, and lessens distortion. By suitable selection of the duration and holding temperatures around M_s, the latter can be reduced to a minimum. Strength increases by 50 to 70% and ductility 2 or 3 times.

(5) Interrupted hardening appears more simple in operation than isothermal hardening and, as long industrial experience has shown, the results obtained are completely satisfactory for many types of tools.

Interrupted hardening is suitable for 9KhS and 9KhVG steels (holding at 150-200° C) and also for Kh(ShKh15) and KhG steels (holding at 150-170° C).

(6) Isothermal hardening requires longer holding periods and precise temperature regulation. It is especially suitable for cutting and stamping tools of complex shape, inasmuch as (*a*) it reduces the deformation on hardening and (*b*) it improves the mechanical properties, where a high degree of hardness has to be maintained (i.e., for tools working at high loads, including percussion tools). Isothermal hardening (with its tendency to increase the amount of residual austenite) should not be used for measuring tools, which must always keep the same dimensions.

To obtain a high degree of hardness, the temperatures for isothermal hardening may be selected 10-15° C higher than in interrupted hardening, and the holding temperature around M_s within the limits of 160 to 180° C. Tempering after isothermal hardening may be effected at a lower temperature (10-15° C less) than interrupted hardening.

References

(1) P. P. Anosov: *Gornyi Zhurnal*, Vol. I, part 2, 1841.
(2) D. K. Chernov, 1885.
(3) S. S. Steinberg: *Metallurg*, Nos. 4-5, 1930.
(4) A. P. Garashchenko: *Mashinostroitel*, No. 24, 1937.
(5) A. P. Gulyaev and A. P. Belova: *Vestnik Metallopromyshlennosti*, No. 1, 1938.
(6) G. A. Oding: *Metallurg*, No. 12, 1937.
(7) A. G. Rachstadt and B. M. Shadkin: "Summary of the Work of the Moscow Mechanical Institute"; publ: Mashgiz, 1952.
(8) V. I. Prosvirin and S. D. Entin: "Thermal Treatment of Metals" (at the "Uralnitomash"); publ: Mashgiz, 1950.
(9) Yu. A. Geller and G. K. Schreiber: *Zhurnal Tekhicheskoi Fiziki*, No. 4, 1941.

Demonstration of the Austenite-Pearlite Transformation by means of the Emission Electron Microscope

By G. BAAS. (From *Philips Technical Review*, Vol. 16, No. 11, May 1955, pp. 337-339, 3 illustrations.)

IN normal electron microscopy the object is irradiated with electrons emitted from a filament. The examination of metals and alloys, using a normal electron microscope, is therefore largely restricted to pictures of very thin replicas of the metal surface. An important advance, permitting the study of metals at high temperatures, is the development of the emission electron microscope, the object itself acting as the electron source.

The temperature region in which the observations are to be made is mainly determined by the phenomena to be investigated. Unfortunately, most metal surfaces begin to emit electrons in quantity only at very high temperatures. An adequate emission at relatively low temperatures can be obtained by evaporating onto the surface a very thin layer of electropositive atoms, e.g., barium or caesium, which lower the work function of the surface of the metal. At the same time, the polycrystalline structure of the metal surface is made visible, because the evaporated atoms are absorbed differently, according to the lattice orientations of the various surface crystallites. A change in this structure, for example, on recrystallization, can therefore be directly observed.

An emission electron microscope developed by Philips is shown in Fig. 1, in which the body of the instrument and a part of the vacuum system with its liquid-air cooler can be seen. By rotating a milled ring on the microscope body and by vertical displacement of the object, magnification can be varied between × 150 and × 3000. The resolving power is 1000 Angstroms. By means of a built-in camera, a series of 40 pictures can be taken in rapid succession on 35-mm film. If necessary, phenomena can also be filmed by means of a 16-mm motion-picture camera mounted under the desk; in this case a transmission fluorescent screen is used and the picture is filmed through the glass of the screen. Naturally, this type of instrument does not have a filament, nor does it possess a condenser lens. Means are included for bringing the object to high potential, and special arrangements are made to ensure the high vacuum required.

Numerous investigations have been carried out with this instrument by Rathenau and Baas. As an example of the work which can be carried out with this emission microscope, Figs. 2 and 3 illustrate the austenite-pearlite transformation in 0·81% carbon steel, prepared under high vacuum to minimize the effect of impurities.

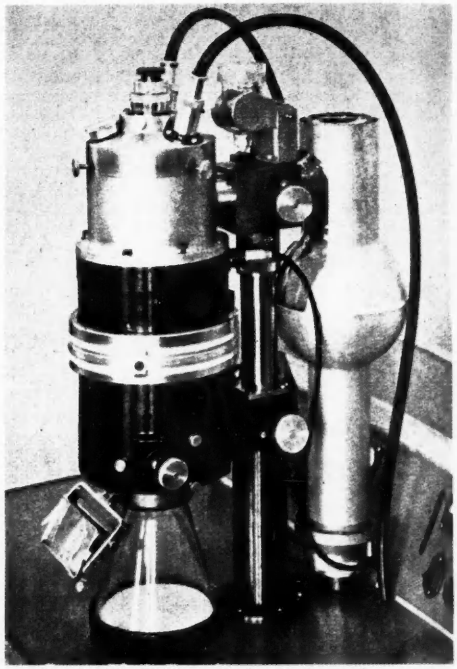


Fig. 1. **The Philips emission electron microscope.**

Fig. 2 shows two pictures, taken at an interval of about two minutes, from a series made during the conversion of austenite into pearlite. Fig. 2 (left) shows the austenitic structure which is stable above 721° C—a homogeneous solution of carbon in γ-iron. Fig. 2 (right) shows the way in which the pearlite grows in the austenite. The pearlite is built up of alternate lamellae of α-iron (ferrite) and iron carbide (cementite). The many dark stripes noticeable in the pearlite are the cementite lamellae.

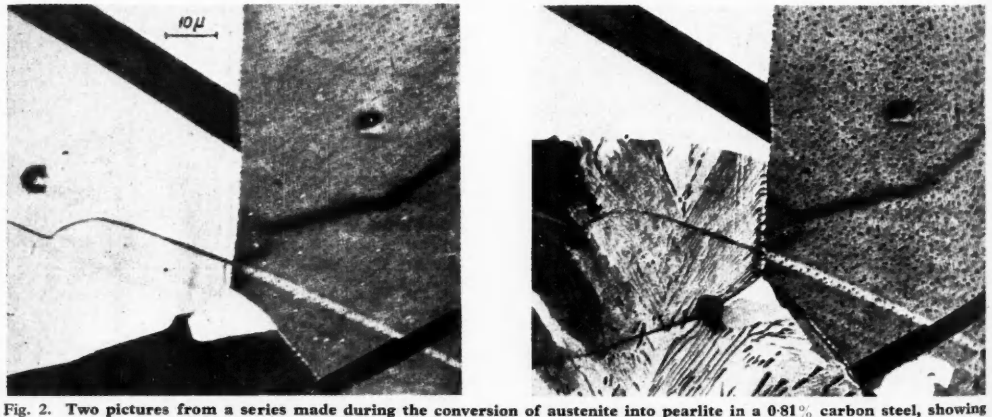


Fig. 2. **Two pictures from a series made during the conversion of austenite into pearlite in a 0·81% carbon steel, showing (left) austenitic structure and (right) austenite partly changed into pearlite.**

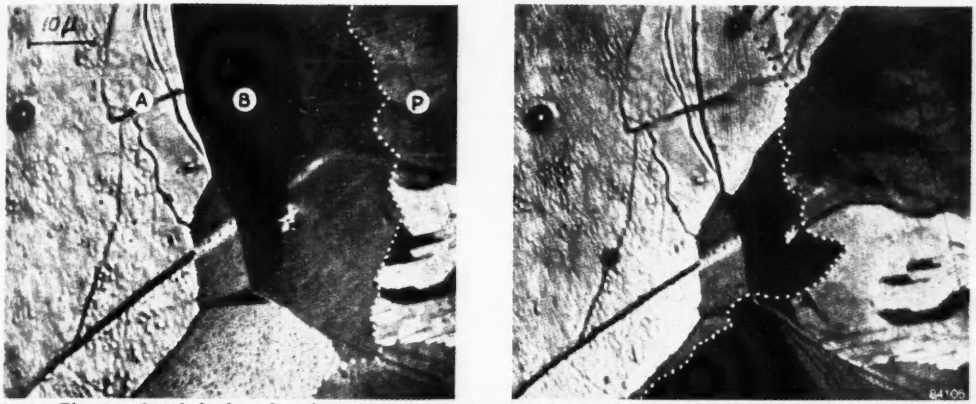


Fig. 3. **Photographs of the boundary between two austenite crystals, showing (left) the initial situation and (right) the situation after the boundary has moved.**

Fig. 3 illustrates a phenomenon often observed in the austenite-pearlite transformation in this carbon steel; if the pearlite, growing in the austenite matrix, reaches the neighbourhood of a boundary between two austenite crystals (left) this boundary tends to meet the approaching pearlite *P*. This can be seen at the boundary between the crystals *A* and *B*. The boundary between austenite and pearlite is indicated by a dotted line. In the part of crystal *A* which has grown in this way at the expense of crystal *B*, numerous fine grooves in the surface can be seen, lying very close together (right). Their presence shows that the displacement of the crystal boundary is a discontinuous process; if the boundary remains stationary for a moment, such a groove forms as a result of the surface tension at the crystal boundary. The series of grooves shows the successive positions taken up by the crystal boundary.

U. S. A.

A Kerr-Cell Shutter with Submicrosecond Speed

By W. Q. NICHOLSON and I. ROSS. (From *Electronics*, Vol. 28, No. 6, June 1955, pp. 171-173, 9 illustrations.)

With the Kerr-cell shutter described in this article, photographic exposures of 0·1 microsecond with an effective aperture of f:7 have been achieved with a standard press camera. The shutter is opened and closed by a narrow 45-kV pulse.

THE necessity for more quantitative information concerning rapidly changing physical phenomena has brought about the development of several high-speed shutters for photographic purposes in the microsecond region. A further increase in speed, to extend into the submicrosecond region, has been achieved with the development of an electro-optical shutter suitable for photography of short-duration luminous phenomena, such as in explosion and ballistic studies.

The Kerr-cell shutter incorporates an exposure time of 0·1 microsecond, a geometric aperture of f:4·5, an effective aperture of f:7 and a view angle of 20 deg. It may be repetitively pulsed at a rate of 60 pulses per second to check cell operation with a synchroscope.

ELECTRO-OPTICAL EFFECT

Basically, a Kerr cell is a transparent container with two electrode plates immersed in a fluid such as nitrobenzene. Polaroid sheets are mounted at either end and are oriented as shown in Fig. 1.

Nitrobenzene is normally an optically isotropic material. The index of refraction and therefore the velocity of propagation are independent of the electric vector orientation of light passing through it. When nitrobenzene is subjected to an electric field, it becomes anisotropic or birefringent for light passing normal to the electric field. The velocity of propagation depends upon the orientation of the electric vector of the light.

The propagation velocity is different for light with the electric vector parallel to the field than for light perpendicular to the field. This difference is proportional to the square of the field strength. The constant of proportionality is defined as the Kerr constant and is

$$(N_1 - N_2)/\lambda = KE^2 \quad \ldots \quad \ldots \quad (1)$$

where E is the field strength; K the Kerr constant $= 400 \times 10^{-7}$; λ the wavelength of incident light; N_1 the index of refraction for light with the electric vector parallel to the field; and N_2 the index of refraction for light with the electric vector perpendicular to the applied field.

By passing polarized light through nitrobenzene with the axis of polarization at an angle of 45 deg. with respect to the electric field, the axis of polarization will be rotated through an angle proportional to the length of the path and the square of the applied field strength. Rotation of the polarized light is due to the difference in

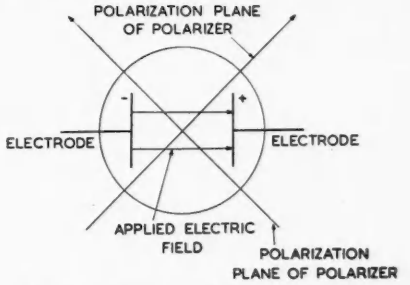


Fig. 1. **Electric field and polarizing vector orientation in a Kerr-cell shutter.**

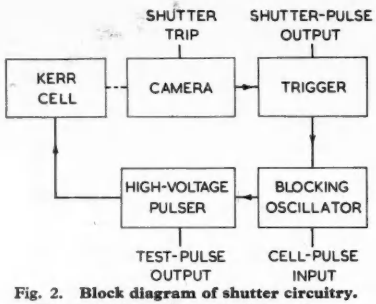


Fig. 2. Block diagram of shutter circuitry.
The dotted line indicates the light path.

velocity of the components which are parallel and perpendicular to the field. This phase angle is

$$\delta = 2\pi LKE^2 \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where L is the path length in the birefringent media.

If the polarizer is arranged with its plane of polarization at 45 deg. to the electric field, the components parallel and perpendicular to the field are equal, as shown in Fig. 1. If the variables of eq. (2) are established such that the phase angle equals one-half the wavelength, $\delta = \pi$, then the emerging light is plane-polarized in a direction 90 deg. to the entering light.

If a second polarizer, the analyser, is placed in the path of the emerging light and oriented with its polarizing plane perpendicular to that of the initial polarizer, the emerging light will pass through the analyser when the proper electric field is applied. The percentage of cell opening T is

$$T = 100 \sin^2 (v/V_o)2\pi/2 \quad \ldots \quad (3)$$

where v is the applied voltage and V_o is the voltage required for full opening.

By application of the above equations it is possible to design a shutter or light valve without moving parts and dependent on the molecular characteristics of the media only. This molecular phenomena occurs in the order of 10^{-9} sec.[1] The speed or shutter open-time is then dependent on how short a voltage pulse can be applied to the electrodes.

Cell Design

Applying the above equations, a cell design was established and calculations showed that a full-open voltage of 45 kV would be necessary. Examination of eq. (3) shows that the transmission as a function of applied voltage is non-linear. This results in a duration of light transmitted which is appreciably shorter than the applied electrical pulse width.

The effective exposure time is defined as 70% of the area under the transmission curve as plotted from eq. (3). For an effective exposure of 0·1 microsecond, the electrical pulse width calculated was approximately twice as wide, or 0·2 microsecond. The pulse shape used as a basis for these calculations was Gaussian in nature.

Generation within a portable case of a 45-kV pulse of 0·2 microsecond duration into a capacitive load presented the main problem. Pulsing techniques previously used were either for small cells requiring much lower voltages[1] or utilized the discharge of a capacitor, resulting in a fairly wide pulse of about 1-microsecond duration.[2]

Breadboard tests of a hydrogen-thyratron and capacitor combination, feeding the primary of a pulse transformer, showed that a 45-kV pulse could be generated, but shaping would be necessary to achieve the desired width.

An experimental cell was constructed using the above parameters as a design basis. At the same time a development programme was undertaken to design and build the pulse transformer and pulse-forming network. Since the secondary pulse fidelity was not of great importance, no attempts were made to achieve theoretical impedance match. 5000-ohm load resistors were found adequate to prevent a long trailing edge on the pulse.

A block diagram of the modulator or pulse unit is shown in Fig. 2. The shutter is opened by discharging a 0·2-microsecond pulse-forming network, which is charged to 14 kV through the primary of a pulse transformer. The pulse-forming network is discharged by a hydrogen thyratron.

When the pulse-forming network charges to 14 kV and the shutter is tripped, the network discharges into the pulse-transformer primary. The 7-kV voltage across the primary is stepped up to 42 kV across the Kerr cell. A 10-ohm resistor in series with 5000-ohm damping resistors provides a low-level pulse-monitor output voltage, which may be observed on a synchroscope.

For photographic purposes the select trigger-switch is placed in the internal or external position. When the camera shutter is tripped, the camera-synchronizing contacts earth the junction of two 33,000-ohm resistors. The external switch position provides a connection for externally delaying the trigger, so that a picture may be obtained at any time after initiating the phenomena to be photographed.

Operation

To verify the predicted exposure time, a multiplier phototube was used in place of a photographic plate. With the unit operating at the rate of 60 pulses per second and an incandescent light source placed in front of the cell, the actual light-transmission pulse was observed on a synchroscope.

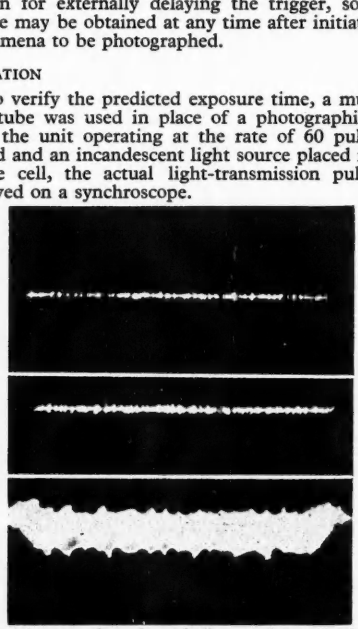


Fig. 3. Photographs of exploding resistance wire, with delays of 8, 15, and 20 microseconds after the application of the vaporizing current.

Actual photographic tests were made by exploding 1-mil diameter resistance wire with a capacitor bank. The photographs shown in Fig. 3 are a series of pictures taken at delays of 8, 15, and 20 microseconds after the application of the vaporizing current to the wire. An external delay device was used to delay the trigger pulse until the desired time interval had elapsed. The non-uniform characteristic of localized heating of a presumably uniform homogeneous wire is attributed as one of the causes of incipient filament failure, owing to generation of hot spots during filament warm-up.

(1) A. M. Zarem, F. R. Marshall, and F. L. Poole: "An Electro-Optical Shutter for Photographic Purposes." NavOrd Report No. 1016.
(2) B. J. Ley and P. Greenstein: "Electro-Optical Shutters for Ballistic Photography." *Electronics*, September 1952, p. 123. M. Sultanoff: "A 0·1-Microsecond Kerr-Cell Shutter." *Photographic Engineering*, Vol. 5, No. 2, 1954.

The Effects of Residual Stresses in Welded Structures

By G. M. Boyd. (From *The Welding Journal*, Vol. 34, No. 5, May 1955, pp. 216s-222s, 5 illustrations.)

There has long been widespread and inconclusive controversy on the influence of residual stresses on the behaviour of welded structures under service conditions, particularly after the occurrence of a number of serious fractures in ships built during World War II and in other structures. For the purpose of this paper, residual stresses are defined as those stresses which would exist within a structure if all the stresses due to external loads were removed, including those due to the weight of the structure. Residual stresses are therefore balanced within the structure itself, and are independent of external loads and reactions, although the application and removal of such external forces may in some circumstances modify the distribution of residual stresses. This paper is concerned only with those residual stress systems arising directly as a result of the use of welding.

Typical Residual Stress Patterns

The stress systems which arise from welding in complex structures are, of course, also complex, but for the purposes of this discussion it will be sufficient to consider, in the first place, the stress patterns which arise in a simple butt weld between two flat plates. In this case there is a high tensile stress at the weld in the direction of the weld axis, i.e., in the longitudinal direction, balanced by longitudinal compressions in the plates remote from the weld (Fig. 1). These longitudinal stresses must be zero at the ends of the plates, and the maximum values are developed only at some distance from the ends, as shown by the dotted curves in Fig. 1. The maximum tension, along the centre of the weld, approximates the yield point of the weld metal; the maximum compression, along the edges of the plates, is comparatively low and its actual value depends on the width of the plates. The greater the width, the smaller is the compressive stress required to balance the tension in the weld. The extent of the tension zone, embracing the weld, is quite narrow, and of the order of the plate thickness.

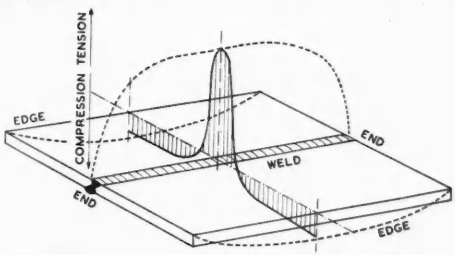


Fig. 1. Longitudinal stresses in a butt weld.

Provided that the edges are free, the stresses transverse to the direction of the weld are small compared with those in the longitudinal direction, and are made up by tensions across the weld in the middle of the length, balanced by compressions across the weld at its ends. If the edges of the plates are restrained, either by increasing the width of the plate or by connecting the edges to rigid structures, the transverse stresses are increased. The additional stresses due to such restraints are usually termed reaction stresses.

Before considering the effects of residual stresses, it is desirable to observe the following property of such internally balanced stress systems generally :—Consider the stress-strain relationship for any given point in a structure (Fig. 2). To produce a given residual stress S the material must be subjected to a certain strain ε_1 which exceeds the elastic limit but, in order completely to relieve the stress, only a very small relaxation is required, which is achieved by reducing the strain to a lower value ε_2 such that $\varepsilon_1 - \varepsilon_2 = S/E$, where E is the modulus of elasticity. Thus, to relieve a residual stress of 17 tsi, a relaxation strain of only about 0·13% would be required. Fracture could therefore occur only if the material were incapable of withstanding a further plastic strain of this small amount. Such a material would be considered brittle.

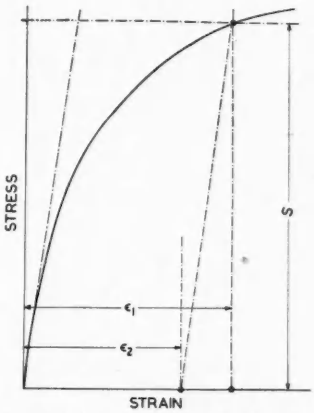


Fig. 2. Stress/strain relationship for a point within an internally balanced stress system.

A further property of the residual stress system in the longitudinal direction, i.e., parallel with the weld, is that a transverse fracture, if it occurs, can only relax the stresses over a short distance along the weld. To relieve the stresses along the whole length of the weld, therefore, a large number of short transverse fractures would be required, unless the stresses could be relieved by other means, such as stretching or heat treatment. The length of such fractures is determined by the width of the tension zone which, as mentioned above, is quite narrow.

Effects of Residual Stresses

The available evidence on the effects of residual stresses on the behaviour of welded structures is reviewed under seven headings, i.e., tensile strength; fatigue; stress corrosion; brittle fracture; elastic stability; reaction stresses; and weld cracking.

Tensile Strength :—

Many investigations have been made on this aspect, but only the following need to be mentioned here :—

Norton and Rosenthal[1] produced controlled residual stresses by local heating in flat-bar specimens, which were later tested in tension. It was found that local plastic flow occurred in the heated region at loads below the yield point of the virgin material. The residual stresses were relieved by tension at the level of the yield point of the virgin material, and subsequently the specimens behaved as if there were no residual stress. Further tests in static bending confirmed these results.

Patton and others[2] made extensive tests on welded girders in Russia, and found that the residual stresses were relieved by local plastic flow under yield-point loads. These workers concluded that: "The safety of the structure will not be obstructed, even if the sum of the working and shrinkage stresses is greater than the allowable stress." They observed local deformations

at low loads, but considered that these did not impair the safety.

Jamieson[3] carried out tensile tests on specimens with welds in U-grooves along the edges, and on plain unwelded specimens. He found that the welding reduced the breaking stress by about 9% and reduced the elongation from 33 to 12%. The fractures started at the welded edges, and this was attributed to irregularities or flaws. After loading above the yield point of the parent plate, the welded specimens behaved, on reloading, in the same way as unwelded specimens.

Wilson and Hao[4] made an extensive series of tensile tests on wide-plate specimens, with and without longitudinal welded joints, and found that :—

(1) Compared with the unwelded specimen, the welded specimens showed greater deformation below the yield point, and less above it. The welded specimens showed higher yield points, slightly lower maximum loads, lower elongations, and lower reductions of area.

(2) Strips containing the welds, cut from wide specimens, showed significantly lower elongations at fracture.

(3) The residual stress was greatly reduced by loading a welded specimen beyond the yield point and then unloading, but this did not appreciably affect the strength or ductility.

(4) In tests on specimens, 40 in. wide by $\frac{3}{4}$ in. thick, longitudinal welds had no significant effect on strength, whether made manually or automatically, and whether low-temperature stress-relieved or not.

(5) The elongations of untreated welded specimens were about 90% of those of unwelded specimens. Low-temperature stress-relieving slightly reduced the elongations.

(6) In general, the fractures started from the welds. This was attributed to lower ductility of the weld metal.

(7) Specimens with circular welds failed outside the welded region, at slightly increased loads.

(8) One of the specimens fractured in a brittle manner, but in this case the fracture started at the edge of the specimen, not at the weld.

Bibber[5] made extensive tensile tests on heavy sections incorporating welds and concluded that :—

(1) At extreme elongations the welds cracked at intervals " to accommodate themselves to the greater ductility of the plate."

(2) Stress-relief annealing (no details given) considerably increased the elongation.

(3) Joints with transverse residual tensions developed slightly less overall strength and elongation than those containing primarily longitudinal stresses.

Fatigue :—

Many experiments have been made to determine the effects of residual stresses on fatigue strength without conclusive results, partly owing to the inherent scatter in fatigue tests, and partly because of the presence of many confusing variables which could not be eliminated without also eliminating the residual stresses. A further difficulty seems to have been the high cost of the many large specimens required.

Wilson and Hao[4] made a series of push-pull tests on specimens of 5 × $\frac{3}{8}$ in. section having longitudinal welded joints in several conditions, i.e., as-welded, with welds planed and draw-filed smooth, and stress-relieved by stretching above the yield point. Unwelded control specimens were also tested. The usual scatter of results was found, and it was concluded that welded plates with high residual stress had a slightly lower fatigue strength than similar plates stress-relieved by stretching, but that the difference did not exceed the scatter of the various tests.

A group of members of the U.S. Welding Research Council, in a report on the weld stress problem[6] concluded :—" A comprehensive series of fatigue tests on large-size welded coupons, and extending over several years, indicates that, under full alternating stress, the endurance limit of unstress-relieved coupons is substantially the same as for stress-relieved coupons."

In a very comprehensive survey of the literature on the effects of residual stresses, Stitt and Chadsey[7] state that any unrelieved residual stress has little or no effect on fatigue.

Harris and Weck[8] carried out fatigue tests in bending by the resonant method on six mild-steel shafts of 4 in. diameter, of which four had a weld bead deposited in a circumferential groove. Two of the shafts were annealed at 650° C. These workers concluded that the six tests indicate that residual stresses may decrease the fatigue strength of mild steel, but they also indicate that this decrease is not very large, and may easily be masked by the effect of weld flaws or other incidental discontinuities. The annealing treatment resulted in a slight improvement, but did not restore the fatigue life to that of the unrelieved specimens.

In the investigation of the effects of residual stresses on fatigue strength, it is necessary to compare identical welded specimens in the as-welded and stress-relieved conditions. It is impossible, however, to ensure that the stress-relieving does not produce other effects, besides removing the stresses. The comparison therefore reduces to a study of the effects on fatigue strength of particular treatments, such as annealing at 650° C, stretching, etc. The effects on fatigue strength of the particular heat treatment known as stress-relieving were discussed by Weck in an unpublished report.[9] This cited the work of several investigators, showing that this heat treatment sometimes slightly improved the fatigue strength, sometimes slightly reduced it, and in other cases had no significant effect.

Stress Corrosion :—

Whereas considerable work has been done on the effect of externally applied stress on the incidence of stress-corrosion cracking, very little consideration has been given to the effect of residual stress in this connection. The effect of residual stress, combined with the presence of certain chemicals in producing rapid failure by cracking, is well known, for instance, in the α-brasses and bronzes. Similar cracking can be induced in mild steel in contact with a number of chemicals, but there does not appear to be any recorded case of failure of this type on mild-steel structures in contact with sea water or with the atmosphere.

Examples of cracking of stressed mild steel in contact with caustic alkalis, inorganic nitrates, nitric acid, and other chemicals are well known. While it is known that similar cracking can develop in welded mild steel in contact with these chemicals, it has not been proved that the cracking results from residual stresses due to welding, rather than to some other effect of welding, such as the metallurgical changes resulting from the welding heat. Clearly, some further systematic investigation of this matter would be desirable.

Brittle Fracture :—

The problem of brittle fracture in ductile materials, such as mild steel, is very complex and, as yet, imperfectly understood. It is natural, therefore, that the effects of residual stresses on the incidence of this phenomenon are not very clear.

Brittle fractures which have occurred in ships have been extensively investigated in America under the auspices of the U.S. Board of Investigation and the U.S. Ship Structure Committee, and in the United Kingdom by the Admiralty Ship Welding Committee.[10] These investigators independently concluded that the residual stresses arising from welding were not an important factor in causing the fractures. It is clear that the Committee, in agreement with other investigators, believes that residual stresses cannot cause brittle fracture in a ductile material but that, if the material is in a notch-brittle condition, residual stresses can produce brittle fracture in the same way as other stresses, provided that a suitable notch is present.

As a result of experiments conducted by Kennedy,[11]

Weck,[12] and Anderson and Waggoner,[13] it may be concluded that welds behaved in the same way as notches, reducing ductility at low temperature, but having little effect at high temperature. Normalizing apparently increased ductility at low temperature, an effect which is frequently observed with notched specimens which are not welded.

That welding is not by itself a cause of brittleness is shown by the ductile behaviour of many welded structures under static and shock loading. Pierce[14] describes a large experimental open-top tank, welded by normal shipbuilding methods, in which explosives were fired under water, causing severe bulging but no leaks. Many cases are on record of welded ships sustaining severe damage through underwater explosions without brittle fracture occurring, except when the temperature was near 0° C.

Offord[15] tested hollow welded drums submitted to underwater explosions, and found that the fractures were sometimes ductile and sometimes brittle, irrespective of whether the specimens were normalized or not. Offord concluded that no increase resulted in the charge required to rupture, and no change was obtained in the type of fracture, if the plates were normalized at 900° C before use and/or heat-treated to 650° C after welding, to relieve locked-up stresses. More recent analyses of the results, however, are said to indicate some benefit from heat treatment.

Elastic Stability :—

Little experimental work seems to have been carried out to evaluate the effects of residual stresses on the elastic stability of slender structures, although welded slender tubes subjected to compression have been found to fail at lower loads than were expected, and this has been attributed to residual stresses.

Logically, it would appear that in such tubes a longitudinal weld would produce unsymmetrical residual stresses, the effect of which should be equivalent to eccentricity of loading. This does not, however, seem to have been verified by controlled experiments.

On the other hand, tests were made at the University of Illinois[16] on slender struts (length-radius of gyration 64-75) for railway viaducts, having welded reinforcement, and the tests indicated that, although there were residual stresses in the columns of 30,000 psi before the columns were loaded, the addition of the reinforcing plates increased the load-carrying capacity in direct proportion to the increase in section, i.e., the reinforcing plates were 100% effective in increasing the load-carrying capacity of the columns, even though residual stresses of 30,000 psi were induced by the welding process. The reinforcements were presumably placed symmetrically with respect to the axes of the columns; otherwise, eccentricity would probably have arisen because of distortion. This, however, should be distinguished from the presence of residual stress.

Reaction Stresses :—

Reaction stresses differ from the residual stresses previously discussed in that they are balanced within the structure on a larger scale. If an insert plate is welded into an opening in a structure, stresses are developed owing to the contractions of the closing welds operating against the rigidity of the surrounding structure and of the insert itself. It is often thought that, whereas the "ordinary" residual stresses may be unimportant, "reaction" stresses may build up to dangerous proportions, particularly in rigid structures.

This possibility was investigated in a series of experiments by Weck.[17] In the preliminary stages of this work, narrow strip specimens were welded in a stiff restraining frame by a variety of procedures. The resulting reaction stresses were much lower than anticipated, i.e., less than 3 tsi. A second series of experiments was therefore carried out in a restraining frame of very much greater rigidity, and reaction stresses up to about 13 tsi were obtained. Although the restraints were considerably greater than are likely to occur in a normal structure, no fractures occurred. A further series of tests was carried out, using wide-plate specimens (two 60 × 30 in. plates welded together to form a 60-in. square) heavily restrained in both directions by attachment to a concrete slab. The resulting reaction stresses were again low, amounting to only about 2·5 tsi.

During the experiment with the rigid steel frame, three specimens were cooled with solid carbon dioxide to about −40° C. Reaction stresses of 15-16 tsi, already in these specimens, were increased by cooling to about 20 tsi, i.e., well above the yield point. No fractures occurred, even though the temperature was well below the transition range of the specimens as determined by notched tensile tests. When the specimens were warmed to room temperature, the original reaction stresses had diminished by about 3 tsi. From these experiments it was concluded:— "Plastic flow and relief of reaction stresses will take place in mild-steel structures, in consequence of differential heating and cooling, even at temperatures far below the transition temperature. Moreover, the combined action of residual stresses and reaction stresses will not result in spontaneous brittle fracture, even at temperatures below the transition temperature, provided that notches are absent."

It is apparent from these and other experiments that, to produce brittle fractures under the action of residual and reaction stresses, two conditions must be fulfilled :—The temperature must be below the transition range of the material, and there must be a notch at a suitable position. These conditions are necessary, but not always sufficient.

It may be conjectured that reaction stresses may have some effect on fatigue strength, since they may have the effect of locally increasing the mean stress produced by fluctuating external loads. Similarly, in some circumstances, reaction stresses possibly reduce the critical loads for local elastic instability. However, there is no experimental evidence to support these conjectures, nor can any reliable record be found of their confirmation by failures in service.

Weld Cracking :—

It is well known that cracking of welds, with occasional propagation of such cracks into the parent metal, is difficult to avoid when welding is carried out "under restraint." It may be remarked that all arc welding must be subject to some restraint, since the solidified metal in the wake of the arc must oppose the contraction of the newly deposited metal.

Recent research by the BWRA, particularly the work of Cottrell,[18,19] has clearly shown that weld cracking is due to brittleness of the metal, induced either by passage through a "brittle" range during cooling, or by the presence of hydrogen in either the weld metal or in the parent material. The same work has shown that the tendency to cracking is little affected by the mechanical restraint but is strongly affected by the rate of cooling, high cooling rates favouring cracking. The rate of cooling is, however, increased by many of the factors which increase restraint, such as thickness and the welding of small inserts into large structures. This probably explains the belief that the restraint is the cause of the cracking. In the light of this experimental work, however, it appears more rational to attribute the cracking to local, and often temporary, brittleness.

Cottrell's work has also shown that cracking is a time-dependent phenomenon, which explains the occurrence of weld cracking some time after the weld has cooled. Such delayed cracking, which has been shown to be closely related to the presence of hydrogen, may result in fracture of the parent material, if this happens to be below its transition temperature.

The remedy for such cracking, therefore, seems to lie, not in the removal of the stresses, but in measures to

control the cooling rate, such as preheating and the use of heavy runs, and in the control of hydrogen in the electrodes and parent metal.

DISCUSSION

There is little or no evidence that the residual and reaction stresses produced by welding are in any way harmful. This conclusion is difficult to accept, for it appears that, if stresses up to the yield point exist in a structure before the external loads are applied, the resulting combined stresses must at some points be additive and must therefore reach dangerous proportions. In fact, however, the picture is not as simple as it might appear on this reasoning.

In the first place, the superimposition of external loads on an internally balanced initial stress system is not a matter of simple addition. Consider the arrangement shown diagrammatically in Fig. 3, i.e., a cylinder with a bolted cover. Before pressure is applied, the bolts are in tension, and this is balanced by the compression in the joints. As the pressure is increased from zero, the compression in the joint decreases, with a consequent reduction in the bolt tension required to balance it. This reduction in the tension is, however, counteracted by the pressure, so that the actual tension in the bolts remains constant up to the point at which the compression becomes zero. Thereafter, the tension in the bolts increases in proportion to the pressure, if there is no leakage. The tension in the bolts is therefore not simply the sum of the initial tension and that due to the pressure. This is, of course, an oversimplified picture, since the deformations have been ignored, but it may serve to illustrate the point.

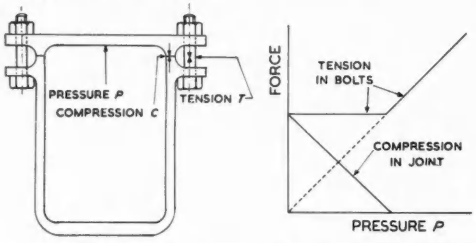


Fig. 3. **Relation of stresses present in a cylinder with a bolted cover.**

A further reason for the fact that the superimposition of stresses is not a simple addition is the occurrence of plastic flow. This has been demonstrated by Meriam, DeGarmo, and Jonassen,[20] and is illustrated in Fig. 4. The stress distributions before, during, and after loading are shown, and it can be seen that the stress at the weld was not increased by the superimposed stress of 20,000 psi. This effect was, of course, due to local yielding, which always occurs in such circumstances, provided that the material is ductile and free from cracks. When the load was released, the stress remaining at the weld was found to have diminished by the amount of the applied stress. Further loading and unloading within the range of the first application of stress would not cause further plastic flow.

Nevertheless, it is known that, in general, stress-relieving is beneficial; it is, in fact, required by many specifications. It is not known, however, whether the benefit is in fact due to the elimination of residual stresses or to other effects, and it is suggested that it is due to metallurgical effects. This was also the conclusion reached by the Weld Stress Committee of the American Welding Research Council, and is embodied in their final report.[21]

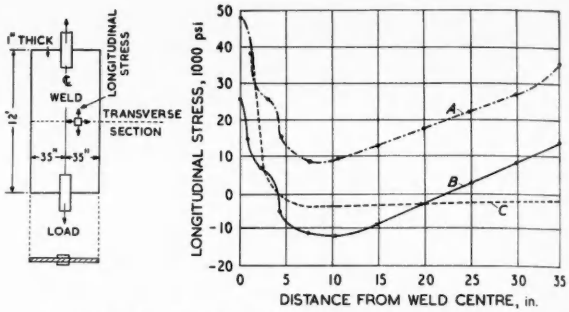


Fig. 4. **Redistribution of residual stresses for a submerged-arc weld, when loaded in the direction of the weld and then relaxed.**

(*A*) Stress of $1{\cdot}4 \times 10^6$ lb load (20×10^3 psi). (*B*) Final residual stress (zero load). (*C*) Initial residual stress (zero load).

It is beyond question that undesirable metallurgical effects may, and usually do, arise in the vicinity of welds. These result from the temperature cycles, which involve melting, solidification, and allotropic transformations, and also from plastic flow at various temperatures, including "cold-working" at some distance from the weld. Moreover, as noted earlier, hydrogen and possibly other detrimental non-metallics may be introduced. In addition, it is known that strain-ageing and quench-ageing occur in steels subject to these phenomena, and these are known to have a pronounced embrittling effect.

The heat treatment known as stress-relieving, i.e., heating to about 650° C followed by slow cooling, is beneficial in removing some of these detrimental effects in some types of mild steel. That this particular form of heat treatment may not always be fully effective has been shown by some recent work under the American Ship Structure Committee.[22]

Other forms of stress-relieving, such as mechanical stretching, which include the process known as low-temperature stress relief, whilst reducing the stresses, probably aggravate the metallurgical effects cited.

REFERENCES

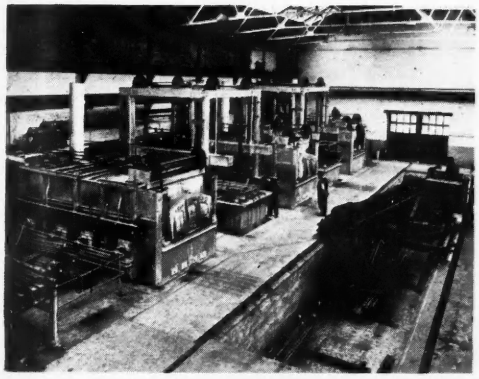
(1) J. T. NORTON and D. ROSENTHAL: *The Welding Journal*, Vol. 22, No. 2, 1943, pp. 63s-78s.
(2) E. O. PATTON, B. M. GORBOUNOV, and D. O. BERSHTEIN: *The Welding Journal*, Vol. 23, No. 9, 1944, pp. 473s-480s.
(3) R. E. JAMIESON: *The Welding Journal*, Vol. 14, No. 9, 1935, pp. 16-21.
(4) W. M. WILSON and CHAO-CHIEN HAO: *The Welding Journal*, Vol. 26, No. 5, 1947, pp. 295s-320s.
(5) L. C. BIBBER: *The Welding Journal*, Vol. 24, No. 4, 1945, pp. 193s-226s.
(6) *The Welding Journal*, Vol. 24, No. 6, 1945, pp. 313s-319s.
(7) J. R. STITT and W. R. CHADSEY: (*U.S.*) *Office of Scientific Research and Development, Report No.* 814, *Serial M.*9, July 1942.
(8) H. HARRIS and R. WECK: *BWRA*, Unpublished Report FE. 19/3, 1950.
(9) R. WECK: *BWRA*, Unpublished Report FE./R.S./2, 1949.
(10) Admiralty Ship Welding Committee Report R.13, 3rd Interim Report, London, HMSO, 1953.
(11) H. E. KENNEDY: *The Welding Journal*, Vol. 24, No. 11, 1945, pp. 588s-598s.
(12) R. WECK: *Welding Res.*, Vol. 6, 1952, pp. 70r-82r.
(13) A. R. ANDERSON and A. G. WAGGONER: *The Welding Journal*, Vol. 25, No. 11, 1946, pp. 789s-801s.
(14) H. W. PIERCE: *The Welding Journal*, Vol. 21, No. 5, 1942, pp. 307-314.
(15) D. E. J. OFFORD: "Brittle Fracture in Mild Steel Plates." (Conference at Cambridge University), *British Iron and Steel Research Assn., London*, 1945, pp. 93-96.
(16) *The Welding Journal*, Vol. 22, No. 7, 1943, pp. 273s-275s.
(17) R. WECK: Admiralty Ship Welding Committee Report R.4, London, HMSO, 1950.
(18) C. L. M. COTTRELL: *The Welding Journal*, Vol. 32, No. 6, 1953, pp. 257s-272s.
(19) C. L. M. COTTRELL *et al.*: *Welding Res.*, Vol. 6, 1952, pp. 2r-12r, 31r-42r, 50r-57r.
(20) J. L. MERIAM, E. P. DEGARMO, and F. JONASSEN: *The Welding Journal*, Vol. 25, No. 10, 1946, page 698s.
(21) *The Welding Journal*, Vol. 28, No. 10, 1949, pp. 271s-274s.
(22) American Ship Structure Committee, Reports SSC-60, 61, and 64, 1953.

British Industrial Developments

Bar Heat-Treatment Plant

A leading speciality of Sanderson Brothers & Newbould Ltd., of Sheffield, is the manufacture of alloy steels required in the heat-treated condition. In order to facilitate production of these steels, this firm has recently laid down a new heat-treatment plant, comprising two hardening furnaces and a tempering furnace, an oil-quenching unit, a water-quenching unit, and a revolving floor-type charging machine.

The hardening furnaces are built on the underfired principle, the dimensions of the working chamber being 5 ft in width × 16 ft 6 in. in length × 1 ft 9 in. in height. The maximum charge is 3 tons. In these furnaces the products of combustion are induced downwards through the load to give balanced, even heating. Temperature control is in two zones. The proportional gas-air temperature-control system is employed, each furnace being equipped with thirty burners having measuring jets for both the gas and air. Waste heat is utilized to preheat the air for combustion by means of a recuperator in the arch and side walls. The hearth is specially constructed with three slots for the reception of the arms of the charging machine. Door operation is by compressed air.



The tempering furnace is built on the overfired principle and is designed for high-velocity circulation of furnace gases up to 700° C. When working above this temperature, up to the maximum of 850° C, circulation is induced as in the high-temperature furnace. If desired, the recirculating fans can be arranged to cut out automatically on the temperature reaching 700° C and to restart when the temperature falls below 700° C. For normal tempering operations, which are, of course, effected below 700° C, the combustion gases recirculate through the load and hearth at high velocity, passing through ports situated between the burner ports. Eight horizontal-type nickel-chrome centrifugal fans operating in cast-iron collecting chambers below the hearth draw the furnace gases through the load and re-inject them into the work chamber. There are thirty burners with identical jets for gas and air, divided into two zones for temperature-control purposes. An air recuperator is fitted. The working-chamber dimensions are identical with those of the high-temperature furnaces.

As stated, the furnaces are designed for proportional gas-air temperature control. For this purpose each furnace is divided into two zones, rear and front, with a pyrometer to record the temperature in each zone. The thermocouples are inserted through the roof of the furnace. A control panel carries six temperature-recorder controllers and ancillary equipment.

The reciprocating oil-quenching machine has an oil capacity, under working conditions, of approximately 4300 gallons. This machine consists of a rectangular tank with a cover and a substantial steel table to hold the bars. On the bars being placed on the steel table by the charger, the table, pneumatically operated, is allowed to sink into the tank. The cover is automatically lowered into position. The quenching table with bars is moved up and down in the tank by four pneumatic cylinders and counterbalance gear, the action being continued until completion of quenching. The oil is continuously circulated during quenching by an electrically driven propeller-type circulating gear. It is also pumped through a cooler installed at the rear of the quenching unit, to prevent overheating of the bath during quenching. The water-quenching unit is similar in general construction to the oil-quenching unit but is not provided with a cover or circulating gear. Circulation is effected by pumping cold water through the tank and thence to drain.

Two prefabricated steel loading tables are provided for building up the charges of bars. One table is adjacent to the hardening furnaces, the other to the tempering furnace. Construction of the tables permits insertion of the arms of the charging machine. Bars are conveyed to the table by overhead crane.

The charging machine is of the rotary type and is arranged to travel across the front of these units in order to load or unload them in one movement. It is provided with three arms, with a travel of 18 ft, formed from two separate horizontal members, one above the other, to enable the load to be lifted, the arms to be deposited without shock, and finally the arms to be withdrawn. The three movements of lift, charge, and travel are each driven by separate motors with full control, the arm travel and the rotation being interlocked so that the machine cannot be rotated unless the arms are fully withdrawn.

Fuel Furnaces Limited, of Birmingham, were responsible for the design and building of the furnaces and for the installation equipment.

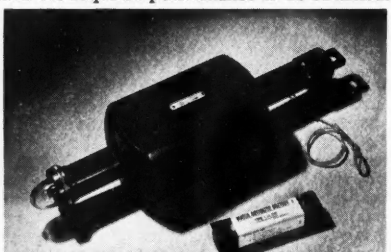
Water-Activated Batteries

The impetus given to industrial research and development first by the war and then by subsequent economic and international difficulties has been reflected in storage-battery engineering by a steady stream of important technical advances. One of the most interesting is the design by Chloride Batteries Ltd., of Swinton, Manchester, of special cell units for " one-shot " and emergency applications.

The original problem was to find an alternative to the water-operated calcium flare once used with life-saving apparatus at sea. Now banned completely by international regulations, these flares were often dangerous, as petroleum or fuel oil might well be floating on the water. The solution was provided by a special water-activated battery which now illuminates small electric lamps on life-jackets, floats, and rafts. Such a battery had to be small, light, and unfailingly reliable even after years of idleness in all climatic conditions—a requirement which ruled out the use of dry batteries. The new water-activated units achieved this combination of virtues so successfully that they have now been developed for many other related applications.

A typical example from the new range of water-activated cells consists of special dry-charged plates of

cuprous chloride designed to suit the particular application ; these remain completely inert, when protected from moisture by sealing tape or some similar means. In an emergency, the tape is ripped off and, as soon as the plates come into contact with either salt or fresh water, the battery is energized. Once initiated, the discharge then continues until the capacity is exhausted. A battery of this type has outstanding advantages for " one-shot " emergency applications. It can be used for high discharge rates for relatively short periods, or for low-rate work over longer periods and has, in either case, an outstanding high performance for its weight and volume. Protected from moisture, it remains completely inert under widely varying temperatures and humidities for an unlimited period. Dependent upon the application, the unit may be designed to function whilst totally immersed in water for the duration of its discharge (as in the case of flares or life-jacket lights) or after an initial wetting, when sufficient water is absorbed to enable the required performance to be obtained.



A number of water-activated batteries of different sizes and capacities has been developed, most of them employing cuprous chloride and magnesium electrodes. The smallest of these, working on a slightly different principle with lead peroxide and magnesium electrodes, is designed to replace the candles once carried by meteorological balloons. Weighing less than half an ounce complete with bulb, it is simply dipped in water and attached to the balloon, after which the light will burn for at least 45 minutes.

Two intermediate sizes in the cuprous chloride-magnesium category have been produced for Mae Wests and other air/sea rescue equipment. Sewn into the life-jacket, the battery illuminates a 1·5 V bulb consuming 0·24 W. The smaller of the two, weighing only 2¼ ounces in its experimental container, will burn for 12 hours and the larger, weighing 4 ounces, for 24 hours.

The fourth and largest of the water-activated batteries in the commercial range, intended for life-saving rafts and floats, will illuminate a 2·5 V, 2 W bulb for at least 24 hours, whilst another version has been specially designed for a lifebuoy light, an example of which is illustrated. Larger units, with a capacity of up to 200 Ah, have also been developed.

100-kW Wind-Powered Electric Generator

Stated to be the most powerful in successful operation anywhere in the world, a 100 kW wind-powered electric generator has been erected by John Brown and Company (Clydebank) Ltd., on Costa Head on the Orkney mainland. Costa Head, which is 400 ft high, was expressly selected for the purpose as being one of the windiest places in the British Isles, gusts sometimes exceeding 125 mph. The mill was designed for the North of Scotland Hydro-Electric Board to feed into the local electricity network, which is normally supplied by diesel-engined generators, and is capable of generating 100 kW at a rated wind velocity of 35 mph and above.

The windmill (Fig. 1) consists of a steel tower of such height that the centre of the rotor is 78 ft above the

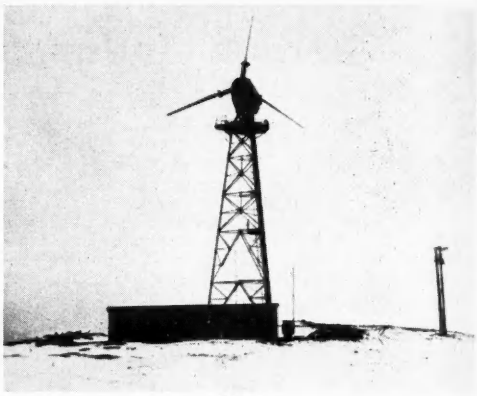


Fig. 1.

ground. On the top of the tower is mounted a nacelle (Fig. 2) which carries the rotor with its three blades and a step-up gearbox which increases the speed from the hub (130 rpm) to 750 rpm—the speed suitable for driving the electric generator. The nacelle is mounted on a pintle shaft to allow the windmill to be yawed round to suit the direction of the wind ; this is achieved by a pinion working on a bull-ring gear and a small electric motor with a speed-reducing gearbox.

The main switch and control gear is housed in a stone building at the foot of the tower. The main electric power and other circuits are conveyed through cables running up one corner of the tower through slip-rings which allow the nacelle freedom to yaw. The machine is fully automatic and starts and stops itself untended, as and when required by the prevailing wind conditions.

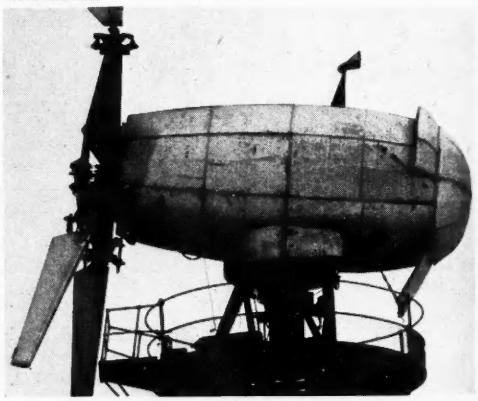


Fig. 2.

The mill has three 17-ft blades attached to a three-armed hub, so that the swept diameter is 50 ft. The blades are of compressed laminated wood with high-tensile steel fittings. They are protected against the weather by a special plastic coating. Each blade is attached at its root to the end of the hub arm by hinged joints which allow it to lean forward or " cone " with the wind forces and to lean in the direction of rotation or " drag " as a result of the turning efforts set up in driving the generator. The hinges—in accordance with normal helicopter practice—remove the excessive bending stresses which would otherwise be set up at the roots of the blades when the mill is running. The thrust of the wind on the blades is opposed by the centrifugal forces which tend to make them fly out. When the

mill is at rest the blades are prevented from flapping loosely on their hinges by locks which are released as the mill runs up to speed. In order to prevent excessive vibration when running, the movement of the blades on their hinges is controlled by telescopic hydraulic dampers. The rotor faces downwind in order to reduce to a minimum the distance between the centre of the tower and the blade rotor and, at the same time, to avoid any possibility of the blades hitting the tower as they revolve.

There is a small " pilot " windmill mounted on the top of the nacelle; this turns at a speed proportional to the wind velocity and signals the main control gear when to start or stop the mill. To prevent a start from a gust in an otherwise calm period, the control gear averages the wind speed over a number of minutes. Once the signal to start has been given, operation follows automatically in correct sequence, controlled by the electrical relays in the control house.

Confident that there is considerable scope for large reliable windmills in many parts of the world, particularly in the North of Scotland, John Brown are now designing a 250 kW model. The design of this model has been guided by experience gained in the construction of the Orkney windmill. Many of the components found redundant at Orkney will be eliminated in the projected model, thus simplifying its construction and maintenance. It will have only two blades, rigidly mounted on a rocking yoke to allow them relief when struck by a gust of wind. John Brown have calculated that this system would provide smoother running and would reduce vibration to a minimum.

Residual Petroleum Fuels for Gas Turbines

During the last three years, experimental work has been in progress at Ruston & Hornsby, Ltd., of Lincoln, to examine the commercial possibilities of the use of residual petroleum fuels on Ruston gas turbines. Much of this work has been carried out in association with Esso Development Co. Ltd., who have also carried out much investigational work in residual fuel burners and an atmospheric combustion chamber.

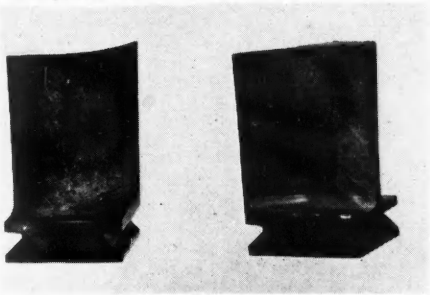


Fig. 1.

In a preliminary series of tests a number of 10-hr screening runs were carried out, to explore the effect of gas temperature over the range from 620 to 770° C and the benefits to be achieved from using various additives, which included magnesium compounds, zinc oxide, and ethyl silicate. It was found from these tests that, with magnesium, a considerable reduction would be obtained in the corrosion rate without increasing deposition. Since these initial tests, a 1000-hr test has been carried out on a fuel containing 3·5% S, together with 50 V, 26 to 62 Na, and 300 total ash, expressed as parts per million. A magnesium additive was used and the test consisted of ten 100-hr runs. The turbine blading was water-washed to remove the small amount of deposit on the blades at the end of each 100-hr run, by means of equipment built into the turbine and fed with mains water. No stripping of the turbine was necessary for carrying out the washing process and no other cleaning was required during the 1000-hr test. The time taken for cleaning was about 2 hours. About 90% of the deposit on the first row of turbine stator blades could be removed in this way, and the turbine swallowing capacity was only 3% less at the commencement of the tenth test than at the commencement of the first.

The first five 100-hr tests were carried out at a mean gas temperature of 700° C, corresponding to rather more than 90% of full load on the TA Gas Turbine. Fig. 1 shows detail views of (left) the convex and (right) the concave faces of a first-row Nimonic 80 stator blade after removal from the turbine on completion of this period of 500 hours running. The blade was found to be in a satisfactory condition for further service and free from serious corrosion.

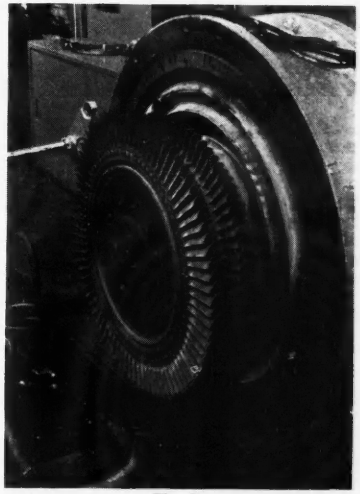


Fig. 2.

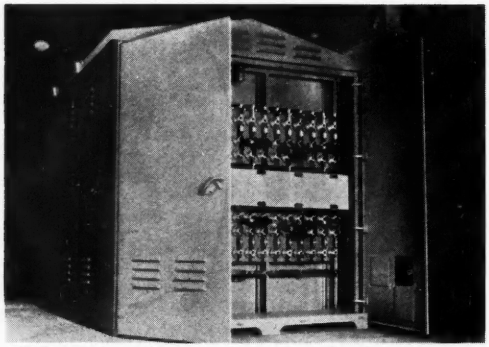
During the next five 100-hr tests, the range of temperatures between 650° and 750° C was investigated, as well as changes in the additive concentration. Fig. 2 shows a view of the 3CT turbine rotor after 1000-hr running on Esso medium fuel and magnesium.

It is now intended to carry out further long tests on the Ruston 3CT gas turbine to determine fully the commercial possibilities of this system and to build up a background of general experience on the operation of gas turbines on residual fuel.

Transformer Kiosks for Russia

A substantial order has been placed by Machinoimport, Moscow, with Crompton Parkinson Ltd. for ring-main transformer kiosks. Each kiosk has three separate compartments which house respectively the high-voltage switchgear, a power transformer, and the low-voltage switchgear. The high-voltage equipment comprises a standard Crompton-Parkinson hand-operated, 300 A, 10 kV off-load, air-break isolating switch for the incoming ring-main feeder, and two air circuit-breakers—one for the tee-off to the transformer, and the other for the outgoing ring-main feeder. The air circuit-breakers incorporated are of a design with a very low breaking capacity and for use with series h.r.c. fuses.

The power transformer is a 320 kVA, 6000 V/400 V, 3-phase unit with star/star connections, manufactured by the C.P. associate concern, The British Electric Transformer Co. Ltd. In the low-voltage compartment (illustrated), ten C.P. specially designed 250 A,



400 V, 3-phase feeder units are fitted. Arrangements are made for coupling any two of these units to switch a single 500-A outgoing feeder with one operation.

The actual kiosks are of a strictly functional design, specially developed in line with the contract requirements. Tubular heaters and adjustable ventilators are incorporated to enable the kiosks to be employed in outside temperature conditions ranging between ± 40° C and, to facilitate shipment, the kiosks are designed to be dismantled into three cases, one containing the high-voltage equipment and compartment complete, another containing the power transformer, and the third containing the low-voltage equipment and compartment complete and the dismantled transformer compartment.

Production-Control Quantometer

The quantometer at the works of Steel, Peech & Tozer, the first to be installed by a British steel company, is a direct-reading instrument designed for rapid routine spectrographic analysis of metals and certain other materials. Although standardized components are used in its construction, each instrument is designed, adjusted, and calibrated to satisfy the particular analytical requirements of the industry or laboratory concerned. This installation covers the analysis of plain carbon steels for residual elements, alloy steels of the nickel, chromium, molybdenum type, blast-furnace sinters, and varying types of steelmaking slags. The selected constituents for analysis are phosphorus, silicon, manganese, nickel, chromium, tin, copper, molybdenum, aluminium, vanadium, titanium, lead, and boron in steels, and silica, iron, lime, phosphorus pentoxide, manganese oxide, magnesia, alumina, and fluorine in slags or sinters.

The quantometer, which was supplied by the European branch in Lausanne, Switzerland, of Applied Research Laboratories, Glendale, California, consists of three units, i.e.,

(1) The source unit, which supplies power to the spark gap. Provision is available for varying the electrical parameters of the discharge to give " spark-like " and " arc-like " excitation.

(2) The spectrometer, which consists of a 1·5 metre grating instrument, in which the Rowland circle is mounted vertically. This covers a spectrum range of 2000 to 7000 Angstroms, with a dispersion of 6·95 A/mm in the first order, and 3·5 A/mm in the second order, using a grating ruled 24,400 lines to the inch. Also included in this unit are the slit frames, mirrors, and multiplier phototubes.

(3) The recording console, which contains the measuring circuits, power supplies, attenuators controlling the phototube sensitivities, automatic timers, and switching mechanisms. Also incorporated is a recorder, which registers each element of a group in sequence at 2·6-sec intervals.

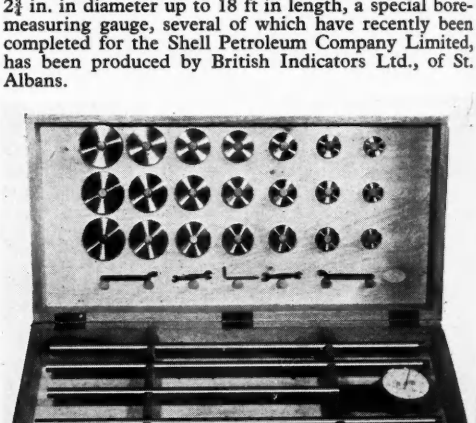
In addition to the above, a power supply to the source unit is provided by a Schindler motor-generator set, to ensure stability of voltage and frequency of the supply. A Zenith stabilizer on the mains is also available in case of emergency. The whole installation is housed in a separate room with special air-conditioning equipment. The temperature is maintained at 70° F, ± 2° F, and the relative humidity at 50%, ± 5%.

A research programme was planned and has been partially completed, prior to putting the instrument into production use. It is now in production use for most of the 24 hours, and is giving very satisfactory results. Transit of the sample to the laboratory takes about 4 minutes, sample preparation 2 minutes, the actual analysis 1 minute, and despatch of the result less than 2 minutes. The time occupied for the complete exercise is therefore about 9 minutes.

As a photometric device, using a constant light source, the instrument has been shown to have a reproducibility of better than 0·2%. In routine use for residual elements up to 0·5%, accuracy is better than 5% of the concentration. For low-alloy steels up to 5% concentration, accuracy is better than 2·5%. In the research programme on highly alloyed steels, accuracy was better than 1% of element concentration. It will be seen, therefore, that the instrument compares very favourably with precision wet chemical analysis.

Special Bore-Measuring Gauge

Specifically designed for the accurate measurement of the bores of tubular drilling equipment from 1¼ to 2¾ in. in diameter up to 18 ft in length, a special bore-measuring gauge, several of which have recently been completed for the Shell Petroleum Company Limited, has been produced by British Indicators Ltd., of St. Albans.



As can be seen from the illustration, which shows the instrument complete in its transit case, the gauge comprises five sections, assembling to a total length of 9 ft, together with a series of guide rings—three for each size of tube to be measured. This enables the completely assembled instrument to be presented to the tube with the assistance of the guide ring mounted in front of the measuring head ; the two additional rings are mounted in any position on the gauge sections, to support the weight of the instrument and to prevent any sag from affecting the accuracy of reading. The measuring head itself is a three-point, self-centralizing design, and the three retractable plungers operate the central push rod. A range of interchangeable tungsten-carbide-tipped contact points is supplied to cover the full range of bores mentioned ; a feature of this instrument is that the measuring head is self-centering by virtue of its three-point design.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

AERODYNAMICS

The Generalized Shock-Expansion Method and its Application to Bodies Travelling at High Supersonic Air Speeds.

By A. J. EGGERS, R. C. SAVIN, and C. A. SYVERTSON. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 22, No. 4, April 1955, pp. 231-238, 10 illustrations.)

THE shock-expansion method has been widely and, for the most part, successfully used in calculating flow about aerofoils travelling at moderate supersonic speeds. This method is, of course, a synthesis of two basic mathematical tools for treating supersonic flows, i.e., the oblique-shock equations of Rankine and Hugoniot and the corner-expansion equations of Prandtl and Meyer. The method has the inherent advantage (over potential flow theories) of accounting for changes in entropy through strong shock waves. In this respect, then, the shock-expansion method is especially well suited for treating hypersonic flows about aerofoils, inasmuch as these flows are usually characterized by strong shock waves.

In this article, it is demonstrated that the shock-expansion method can be generalized to treat a large class of hypersonic flows, only one of which is flow about aerofoils. This generalized method predicts the whole flow field, including shock-wave curvatures and resulting vorticity, providing that (1) disturbances originating on the surface of an object are largely absorbed in shock waves with which they interact, and (2) disturbances associated with the divergence of stream lines in tangent planes to the surface are of secondary importance compared with those associated with the curvature of stream lines in planes normal to the surface. It is shown that these conditions may be met in three-dimensional hypersonic flows. When they are met, surface stream lines may be taken as geodesics, which, in turn, may be related to the geometry of the surface.

The validity of the generalized shock-expansion method for three-dimensional hypersonic flows is checked by comparing predictions of theory with experiment for the surface pressures and bow shock waves of bodies of revolution. The bodies treated are two ogives with fineness ratios of 3 and 5. Tests were conducted at Mach numbers from 2·7 to 6·3 and angles of attack up to 15 deg. in a 10 × 14 in. supersonic wind tunnel. At the lower angles of attack, theory and experiment approach agreement when the ratio of Mach number to fineness ratio, i.e., the hypersonic similarity parameter, exceeds 1. At the larger angles of attack, theory tends to break down, as would be expected, on the leeward sides of the bodies.

AUTOMATION

Machines in the Service of Man.

By F. G. WOOLLARD. (From a paper presented at the Margate Conference of *The Institution of Production Engineers, London*, June 16 to 19, 1955.)

AFTER a preliminary survey of the nature and advantages of automation, the author of this paper discusses some of its likely effects on society in general, and on management and staff. In this connection, it would appear that management in all its phases will have to be more thorough, more co-operative, and more communicative. The number of supervisors and junior executives required in the automatic factory will be greater than in those of to-day. They will be more in charge of machines than of men, of whom there will be few. They will be alert to every change in the tempo of the machinery, and will need to cultivate an indefinable sixth sense which will enable them to detect immediately anything likely to impede the natural flow of production. Furthermore, although there will be fewer workers, there will be a greater need of understanding between them and the supervisors.

Insofar as the men on the shop floor are concerned, there will be stock men and there may be machine loaders and unloaders, though it is likely that these latter functions will eventually be taken over by inter-operation devices. There will, of course, be sweepers and cleaners, but even their functions may become part of the automatic set-up. There will also be viewers, until the function of inspection in turn becomes automatic. Then, presumably, the viewer will become an electronic technician. Most of the men must be first-rate mechanics, and all must be keen and intelligent.

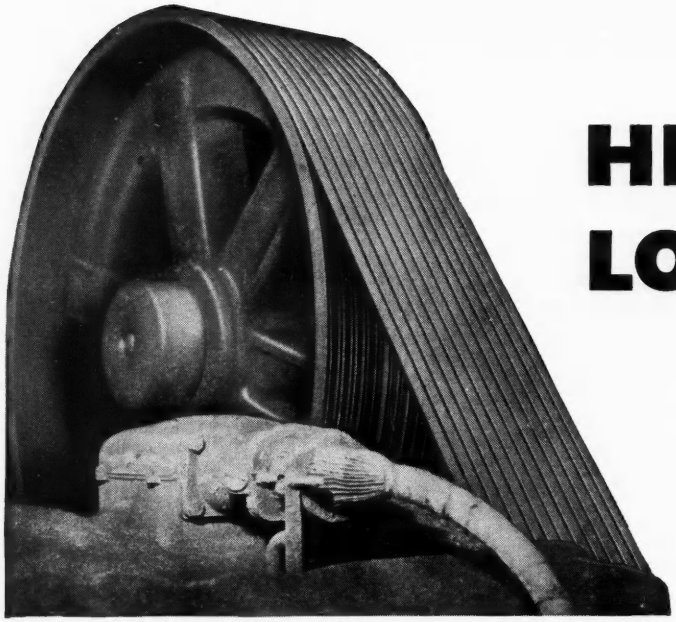
Automation will have other effects. Thus, for instance, it will be necessary to reconsider the method of payment of the men in charge. Piecework, as it is understood at present, will not be applicable. Furthermore, time study, as a shop-floor technique, will disappear, as time study will be a preliminary to the design of the machines and will be, as it were, built into them. The method of calculating overheads as a percentage on the cost of labour will become a complete anachronism and must disappear in favour of machine ratings.

The paper also refers to the question of displacement and the attitude to automation of trades unions, both in Great Britain and the U.S.A. The author believes that automation will not develop in Great Britain so quickly as to cause an acute unemployment problem, though it must be remembered that there may be some displacement of factory personnel which the automated factory will not be able to absorb. If this occurs, it will be incumbent on employers, trades unions, and the Government to co-operate in such a way as to make redeployment as easy as possible for those affected.

Automation will, in the long run, lead to shorter hours, or higher wages, or both. That this is inevitable is shown by the whole history of technological improvement, but it is to be hoped that management, on the one hand, will not be too tardy in meeting the situation, and that unions, on the other hand, will not press their claims too quickly.

Insofar as the consumer is concerned, automation can produce more abundantly, more cheaply, and more accurately. As a result, it will open the door of opportunity to a much greater public. The extent of mass consumption, due to automation, will probably lead to changes in the methods of distributing goods, and some of the larger concerns are already giving consideration to this aspect of the new abundance.

There is little doubt that, as automation grows, it will lead to greater leisure, and there may be some problems in that connection. It is difficult to foresee the future in its entirety, but it should be understood that automation can apply only to certain types of production and that it will not touch the bulk of employment at all.



HEAVY LOADS?

The *right* belting used in conjunction with a correctly designed layout are essential factors in coping with heavy loads. Goodyear will supply the finest flat transmission or 'V' belt for your operational needs, and Goodyear representatives will give you technical advice on the equipping and maintenance of installations. This unequalled service will result in maximum efficient life and performance from your belting — even under the most exacting conditions.

E. C. V-BELT *Built to withstand high starting torques, stalls and shock loads, these belts are ideal for all industrial V drives. They combine great strength with a natural elasticity which absorbs the effects of sudden jolts, yet maintains a secure, lasting grip in the pulley. Used where severe load characteristics are the main criterion these Goodyear belts have constantly proved their outstanding reliability on heavy duty, multi-V drives.*

For longer wear | at lower cost

GOODYEAR INDUSTRIAL RUBBER PRODUCTS

TRANSMISSION BELTING • V-BELTS • CONVEYOR BELTS • INDUSTRIAL HOSE

CORROSION

Advantages of Wood-Lined Steel Pipe in Corrosive Services.

By E. H. BRONSTEIN. (From *Corrosion, U.S.A.*, Vol. 11, No. 5, May 1955, pp. 23-27, 1 illustration.)

WOOD is still extensively used as a material for transporting corrosive or abrasive substances. When the extensive use of wooden pipe in waterworks practice and industry began to yield to cast-iron and steel pipe around the close of the nineteenth century, properties found especially valuable in wood pipe caused it to be retained for applications where iron and steel proved not as fully serviceable or as economical or where ferrous metals were deemed altogether unsuited. Some of the properties are :—

(1) A natural immunity to electrochemical corrosion. Since no ions from dissolving metal are present, serious contamination of the fluid in the pipe by corrosion products is therefore precluded.

(2) Inherent resistance to many chemical exposures affecting steel adversely or rendering the use of suitable alloys economically prohibitive.

(3) Characteristic wear-resistance of certain species, such as maple and beech, which are known to withstand prolonged abrasive action.

(4) A distinctive capacity for lowering pipe friction, assuring smooth fluid flow with increased delivery.

Wood pipe is used to an extent far greater than is generally supposed, especially in the more abrasive and corrosive operations. Typical materials handled by wood pipe or wood linings are aggressive waters from mine drainage and from chemical processes, abrasive slurries of many origins, wood pulps of virtually all descriptions, and natural and processed brines ; acid fumes, gases, and vapours ; refinery waste liquors ; and acid, alkaline, and saline solutions.

Short-term laboratory and lengthy service experience have shown that, even under pressures up to 100-200 psi, liquids seldom penetrate halfway through standard thicknesses of staves. This keeps corrosion at the wood-steel interface of wood-lined pipe at a minimum. Other assets are sustained low friction coefficients and a degree of insulation from temperature.

ELECTRIC MOTORS

Vibration in 2-Pole Induction Motors Related to Slip Frequency.

By E. W. SUMMERS. (From *Power Apparatus and Systems* (*A.I.E.E.*), *U.S.A.*, No. 17, April 1955, pp. 69-72, 2 illustrations.)

VIBRATION and noise in a 3-phase 2-pole a.c. motor are quite often characterized by a pulsation or beat in the amplitude, i.e., the amplitude of the vibration and noise increases and decreases at a uniform frequency related to the slip of the rotor. In many applications, these pulsations are not detrimental to the performance of the machine, but they have an adverse psychological effect upon anyone in the vicinity of the machine because a pulsating noise is much more noticeable than a steady noise. Performance can be influenced in applications where an a.c. motor is built into a common frame with another machine, such as a d.c. generator. With this construction, the pulsations can cause a variation in commutation or in the generator output voltage.

Vibrational pulsations of this nature encountered in 2-pole motors are of the order of from 0·5 to 10 cps, depending upon the slip of the rotor and the type of pulsation. A normal human ear cannot hear vibrations much under 15 cps but, as these pulsations are definitely audible, it is reasoned that the pulsations are not a single fundamental frequency but must be the result of co-operation between two different frequencies, at least one of which is in the audible range.

Two types of pulsations are encountered most frequently. The most common varies at twice slip frequency, and the second varies directly with slip. The purpose of this paper is to describe the fundamental conditions which must exist to produce pulsations of the nature described and to show how, in 2-pole a.c. motors, certain mechanical and electrical dissymmetries co-operate to produce vibrational driving forces which meet these conditions.

A perfectly symmetrical 2-pole 3-phase a.c. motor would not be afflicted with vibration pulsations, although it still might vibrate. The conclusions reached in this article are that, to eliminate vibration pulsations, it is essential :—

(1) To make the stator bore, air gaps, and rotor as accurate and uniform as practical.

(2) To make the shaft straight, without non-circular cross-sections, and with perfectly round ball-bearing fits. These factors are of less importance if the natural frequency of the shaft is well removed from twice running frequency.

(3) To keep the natural frequency of all parts, particularly the shaft and stator core, away from running frequency and twice line frequency.

(4) To make the rotor symmetrical electrically, and to use a stator-winding pitch which suppresses the space harmonics, particularly either or both the 5th and 7th harmonics.

IRON AND STEEL

The Yield Rate of Mild Steel.

By F. FORSCHER. (From *ASTM Bulletin, U.S.A.*, No. 205, April 1955, pp. 63-67, 9 illustrations.)

THE yield-point phenomenon of mild steel can roughly be subdivided into three parts, i.e., the upper yield point, the drop-off, and the lower yield point, each of which is dependent on temperature and strain rate.

The upper yield point represents the load at which the specimen—for a given temperature, strain rate, and geometry—has reached an internal instability condition. It is very sensitive to slight eccentricities of load and may also depend on the surface finish and on the surrounding media. The behaviour between the upper and the lower yield point represents a dynamic instability condition, dynamic with respect to both external as well as internal conditions. It is greatly influenced by the stiffness of the loading mechanism. The lower yield point represents the load at which the specimen—for a given temperature and strain rate—is in dynamic equilibrium with the load-applying mechanism. A special case of this equilibrium condition is the static equilibrium.

The lower yield stress, as usually reported, is the stress under which yielding seems to progress more or less uniformly throughout the gauge length of the tension test specimen being pulled at a constant rate and under constant temperature ; thus, it reflects a dynamic equilibrium condition. If the testing machine were stopped, the stress would drop off to its static equilibrium value. This secondary drop-off may be more or less pronounced, depending on the temperature of test and the original rate of deformation. On the other hand, if the nominal stress at the lower yield point is held constant, as can be effected in a creep-testing machine, and the temperature is increased, it is found that the yield rate increases. This behaviour is expected because the dynamic equilibrium is disturbed, and therefore, under the prevailing constant stress, a new dynamic equilibrium rate of deformation must be reached.

This paper describes experiments designed to establish the yield rate of mild steel under various stress and temperature conditions, and discusses the results in terms of nucleation and growth of Lüders' bands.

Level control?

SILCOCKS

CATTLE, PIG AND POULTRY FOODS

use

Fielden INSTRUMENTATION

. . . and so do thousands of other well known concerns throughout the world. In the past two years alone we have solved 2,500 level problems, and have added many "household names" to our list of Fielden users.

The Fielden method is the most economical, reliable, simple and trouble-free means of level control. Liquids, corrosive or otherwise, powders, granular solids, whether in conditions of vacuum, pressure, or temperature, all fall within its scope. Indication can be by lights, bells, or other alarms, on site or remotely, or arrangement made for control of electric or other valves.

Our wide experience is at your service and our Engineers will gladly advise on any level problem.

Please write to :—

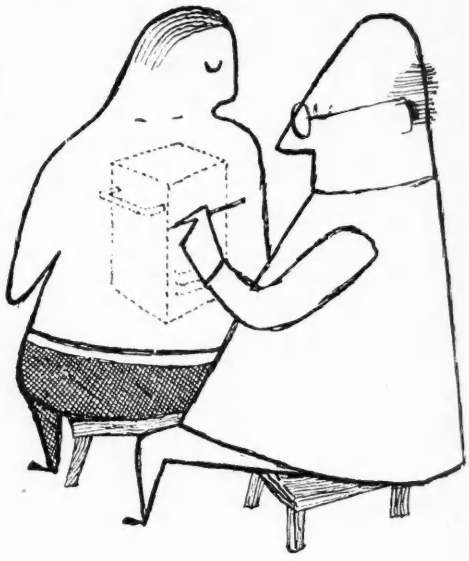
Fielden INSTRUMENTATION

FIELDEN ELECTRONICS LTD.

LEVEL DIVISION 7

WYTHENSHAWE, MANCHESTER.

Tel.: WYThenshawe 3251 (4 lines) Grams: Humidity, Manchester
London Office: 21 Buckingham St., W.C.2. Tel: TRAfalgar 3154



a case of design . . .

There's such a thing as going too far, of course . . . But design is important. First impressions count a great deal. The outward appearance or casing of your product can make or break it—at least, through the buyer's eyes. Imhof's—as designers and manufacturers of all types of sheet metal casings—offer you a specialist service ready to meet your needs—for the bulk production of casings, racks, cabinets and control consoles of any size and in any quantity. There's the famous Imhof standard range of housings—any one of which may suit your requirements. If you wish, we will design exclusively for you: build prototypes and then produce. Could you ask more? Write or phone for further information: or call and see for yourself.

for worthwhile cases, racks, consoles and cabinets

IMHOFS

ALFRED IMHOF LTD.

Dept. K4, 112-116 New Oxford St., London, WC1. Museum 787

OPTICS

Variation in Distortion with Magnification.

By A. A. MAGILL. (From *Journal of Research of the National Bureau of Standards, U.S.A.*, Vol. 54, No. 3, March 1955, pp. 135-142, 11 illustrations.)

THE growth of photogrammetry, with its high-precision imaging systems, has necessitated accurate determination of the distortion introduced by a lens. Because such distortion varies with magnification, it has been customary in the past to have the distortion measured for each object-to-image ratio employed. To avoid making such a series of measurements, a simple linear equation for a lens with a single effective stop has been developed, from which the distortion at any magnification may be computed from the measured values obtained at two magnifications. The two distortions which would normally be used are those obtained with parallel light, incident in turn on the front and on the back of the lens. These not only require the simplest experimental set-up but also have special significance as the limits of real image formation. In this paper, virtual images (i.e., negative magnifications) are excluded as having little practical value.

The findings reported show that for low-aperture symmetrical lenses, the distortion at finite object distances can be simply computed from the two values obtained with parallel incident light with about the same accuracy as the direct experimental measurement. The necessary modifications required in carrying out this computation on other types of lenses are indicated, and it is hoped that experimental verification of these procedures will soon be available.

THERMODYNAMICS

Thermodynamic Properties of Methane-Nitrogen Mixtures.

By O. T. BLOOMER, B. E. EAKIN, R. T. ELLINGTON, and D. C. GAMI. (From *Institute of Gas Technology Research Bulletin, U.S.A.*, No. 21, February 1955, 54 pages, 30 illustrations.)

THIS bulletin presents data on the thermodynamic properties of methane-nitrogen mixtures, required for computing the energy requirements of processes to separate nitrogen from natural gas by liquefaction and distillation, for calculating compressor and expansion turbine energy requirements, for determination of heat-exchange loads, for calculating throttling temperature drops, and for other uses. Examples of the use of the data in these calculations are given.

Two mixtures of methane and nitrogen, one containing 10% and the other 30% nitrogen, were selected for demonstration. The enthalpies, entropies, and compressibility factors of the mixtures are presented in tabular form and as charts of enthalpy against entropy, entropy against temperature, and compressibility factor against pressure. The range of these charts and tables for the vapour phase is from saturation at −284° F to superheated vapour at 200° F and pressures from 10 to 1500 psia, and, for the liquid phase, from saturation at −258° F and 100 psia to the critical point.

For the superheated-vapour region, the properties of the two mixtures were calculated by use of the zero-pressure heat-capacity data and an equation of state for methane-nitrogen mixtures. For the two-phase liquid-vapour region, calculations were based on experimental pressure-volume-temperature data obtained at the Institute of Gas Technology for mixtures of methane and nitrogen.

Constant-pressure enthalpy versus composition charts are also presented for pressures of 100, 200, and 300 psia. These charts were constructed with data on mixtures containing 10, 30, and 70% nitrogen, and published data on the thermodynamic properties of pure methane and pure nitrogen.

WELDING

A Mathematical Analysis of the Temperature Distribution during Flash Welding.

By E. F. NIPPES, W. F. SAVAGE, H. SUZUKI, and W. H. CHANG. (From *The Welding Journal, U.S.A.*, Vol. 34, No. 6, June 1955, pp. 271s-285s, 16 illustrations.)

IT has long been realized that the temperature distribution in any material may be predicted if a simple relationship can be established among material constants and flashing variables. With the new flashing parameters introduced in this paper, all temperature distributions resulting from a given flashing pattern can easily be correlated.

A mathematical analysis of the flashing operation, as well as the nature of the stabilized temperature distribution established during flashing, has led to the introduction of a new set of universal parameters, with which the temperature distribution resulting from any given flashing pattern in a material may be correlated with a single, standard distribution form. The validity of such a distribution form for parabolic flashing has been satisfactorily verified by the experimental data obtained for aluminium alloys, steels, and molybdenum.

The effect of flashing variables, such as material constants, specimen size, rate of platen movement, and initial clamping distance, on the stabilized temperature distribution is discussed. Methods are proposed for choosing an adequate mean value of thermal diffusivity for a given material and for evaluating the amount of critical burn-off necessary to establish the stabilized temperature distribution. Examples are given for predicting temperature distributions and predetermining satisfactory flashing conditions.

It is hoped that the present analysis will not only contribute to the understanding of the flashing operation and the nature of the temperature distribution, but will also eliminate much of the costly experimental work necessary to establish optimum flashing conditions.

WIRE AND WIRE PRODUCTS

Controlling Extrusion of Foam Plastic on Wire.

By R. D. GAMBRILL. (From *Electronics, U.S.A.*, Vol. 28, No. 4, April 1955, pp. 144-145, 2 illustrations.)

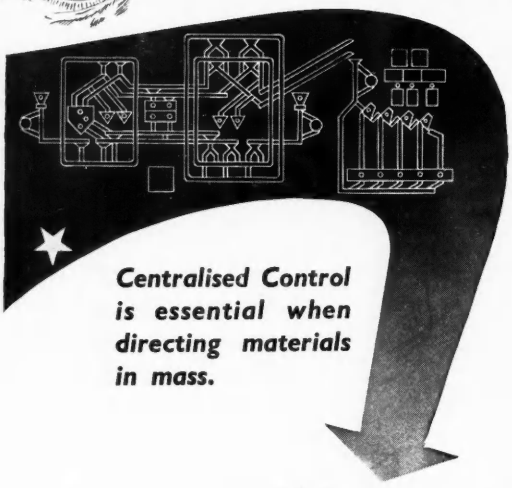
IN the manufacture of telephone cables, capacitance to ground, equal capacitance of a pair of wires to other pairs, and uniformly distributed capacitance to the cable sheath are important to minimize interference to transmission.

The capacitance between the metallic conductor and the outside of the insulation of the individual conductors should be held as constant as possible. With solid dielectrics, the diameter of the insulation is precisely related to the capacitance, so that either diameter or capacitance gauging may be used.

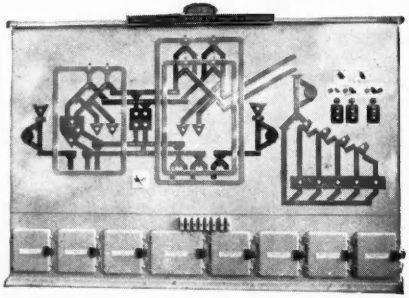
With the expanded plastic insulations, however, neither diameter nor weight measurements nor a combination of these have a suitably precise relationship to capacitance, because the percentage of gas and the size and distribution of the gas cells are factors in determining capacitance. It was considered necessary, therefore, to develop a means of continuously measuring the conductor capacitance and automatically controlling the extrusion of the expanded plastic insulation to hold capacitance within limits.

The system described in this article utilizes a special sensing probe as one arm of a capacitance bridge which is normally balanced with respect to a 10-kc oscillator signal. The oscillator output is then compared with the bridge unbalance on an oscilloscope and in a mixer, which determines the directional error. The output of the mixer is amplified to control a rheostat driven by a servo-motor, which in turn controls a variable-speed drive, mechanically coupled to the wire-pulling capstan.

visual flow indication



Centralised Control is essential when directing materials in mass.



Take for example, this BROOKHIRST VISUAL FLOW DIAGRAM CONTROL BOARD supplied to the Stoke-on-Trent Gasworks for controlling the handling of coal and coke. The diagram is illuminated and represents schematically the relative disposition of conveyors, hoppers, retorts, etc. Colour coding gives precise material flow data, and sixty different flows are obtainable. The desired route is selected by hand-operated switches linked to shute switches, etc. A master "Start" button brings each motor into use automatically in prearranged sequence. The contactor type motor starters are grouped in two switchboards at either side of the flow diagram board.

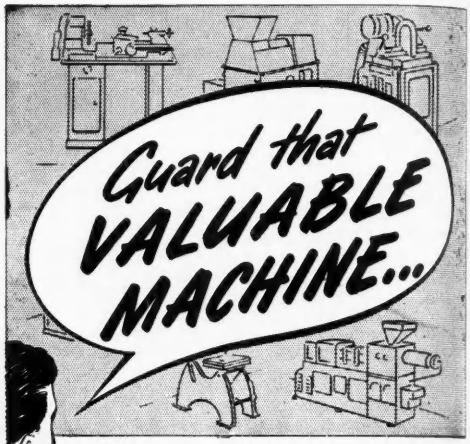
BROOKHIRST

VISUAL FLOW CONTROL

BROOKHIRST SWITCHGEAR LTD NORTHGATE WORKS CHESTER

A METAL INDUSTRIES GROUP COMPANY

BS4/F/353



Your machines will deteriorate rapidly if the corrosive action of acids, alkalis and industrial gases is not checked. **'SUPRUBA'** *chlorinated rubber Machinery Paint protects your plant and equipment against this menace.* **'SUPRUBA'** is also resistant to water, suds and cutting lubricants. Available in 16 shades to provide full scope for 3-dimensional colour schemes. Easily applied and rapid drying.
Ask your secretary to write today for **'SUPRUBA'** literature.

SUPRA
REGD TRADE MARK

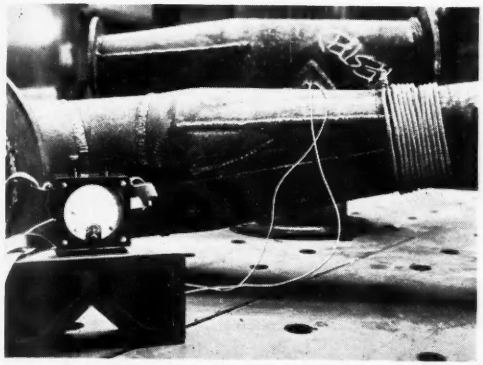
SUPRA CHEMICALS AND PAINTS LTD
Hainge Road • Tividale • Tipton • Staffs
TIPton 2511/2

LG

New Materials, Processes, and Equipment

ELECTROTHERMAL ARMOURED HEATERS

With advances in welding techniques and the increased use of alloy steels, an efficient mobile method of preheating and stress relieving is essential. The use of furnaces is often impossible or uneconomical, while heat treatment on the site often presents a variety of problems. These difficulties are reported to have been satisfactorily solved by means of the electrothermal armoured heaters manufactured by Electrothermal Engineering Limited, of London, E.7. These heaters have been developed to provide the high temperatures necessary for both operations, and at the same time to meet on the site the heat-treatment conditions required by the various alloy steels.

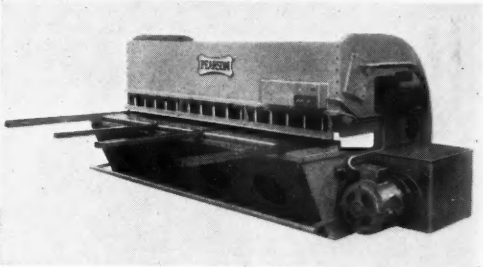


The electrothermal armoured heater is flexible and can be wound around most pipes and vessels with ease, permitting controlled heat to be applied. Three standard types are available, each of $\frac{5}{16}$ in. diameter, with a minimum bending radius of $2\frac{1}{2}$ in., and intended for operation on 110 V a.c. or d.c., but with respective lengths of 16, 20, and 24 ft and loadings of 2·5, 3·7, and 5·0 kW. Current can be supplied by a welding generator or other suitable power source.

To increase thermal efficiency, some form of thermal insulation is essential. This can be sectional asbestos, magnesia lagging, asbestos tape, etc. The complete equipment will consist of the armoured heater, leads, insulation, a thermocouple, compensating leads, a pyrometer, and means of control for varying heat input. As an example of the performance of these heaters, the 20-ft heater, applied to a 9-in. diameter steel-alloy pipe with a wall thickness of $\frac{3}{4}$ in., raised the temperature from an ambient of 54° F to about 1300° F in 45 minutes, using a 2-in. asbestos-tape lagging.

ELECTRO-HYDRAULIC GUILLOTINE SHEARING MACHINE

An electro-hydraulic guillotine shearing machine for steel, with a special rotary-type ram requiring no maintenance or lubrication, is announced by T. B. Pearson & Sons Ltd., of Newcastle upon Tyne. Two models are being produced—a 10 ft × $\frac{3}{8}$ in. capacity and an 8 ft × $\frac{3}{8}$ in. capacity. Low running costs are claimed for the machines because of their hydraulic operation. There are no mechanical components subject to wear, such as gears or crankshafts. Other advantages claimed are high cutting accuracy with no burrs or warps, speed of operation (12 strokes per minute), and simple construction.



The frame of the machine is of welded steel and the standard type has an 18 in. gap, enabling strips which are longer than the working length to be cut. Space between the side frames is completely free, to allow the passage of plates of the full working width. Because the ram is rotary in action no guideways are needed. The ram swings around two trunnions fitted with roller bearings. The cutting blades are of rectangular section and have four cutting edges. The lower blade is mounted on an adjustable beam, which provides easy access and permits the blade to be changed in a short time, when necessary. Low wear on the blades is claimed because friction occurs only locally at the spot where the actual cutting takes place. Variations in the thickness or flatness of the plate are taken up by hydraulic jacks mounted in front of the blades. These jacks come into operation at the first pressure on a foot pedal which operates the machine, and clamp the plate in position. Full pressure on the pedal then completes the shearing action.

The hydraulic unit is completely immersed in an oil tank mounted on the right of the machine. The unit consists of the pump, safety valve, and main steering block. Fitted to the side frames of the machine are the cylinders, which are connected to the steering block by high-pressure solid-drawn pipes. The pump is of the multi-cylinder radial type, with an automatically variable delivery and a speed of 1465 rpm. Because it will open at pressures higher than the permissible values, the safety valve has a fixed setting to avoid any overload.

A control panel on the front of the machine permits push-button control of the backstop from 0 to 30 in. A counter is fitted on the panel and hand adjustment for accurate setting down to 0·01 in. is possible. Inset scaled strips are also fitted to the extension arms of the table, which has spherical rollers for easy handling of heavy plates. A 25-hp squirrel-cage electric motor, 400/440 V, 3-phase, 50 cps, is fitted, together with the necessary switch and fuse gear.

HIGH-EFFICIENCY AIR FILTERS

It sometimes happens that the dust separation provided by the normal high-efficiency filter in the 5- to 10-micron range is inadequate for certain specific purposes, where, for instance, particles between 0·1 and 5 microns can cause trouble comparable with that produced by coarser matter.

Of the various types of special high-efficiency filters devised to meet these requirements, filters employing deep, high-efficiency fibrous "laps" as media are capable of extremely high dust-retention efficiency, placing them justifiably in the "absolute" category, representing almost complete separation of particles of all sizes. However, although such filters, usually taking the form of cylindrical- or rectangular-section canisters,

MEKELITE

GEARED JOINT

INDUSTRIAL LIGHTING UNITS

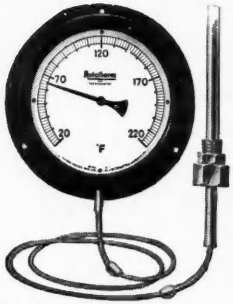
Catalogue free on request.

The Geared Joints give a full 360 degree movement and ensure throughout that the length of cable wrapped on to one pivot is equal to that unwrapped from the other. Unsightly loops, nipping of cable, and pull on terminals are thus eliminated.

Various lengths of arm (maximum horizontal reach 54 in.). With pillar or short vertical pivot. Six sizes of reflector. Bases for wall, bench, ceiling, floor or for mounting direct on machines. Also portable types.

MEK-ELEK Engineering Ltd.
17, Western Road, Mitcham, Surrey
Telephone: MITcham 3072 Cables: Mekelek, London

to indicate, record or control temperature



DISTANT READING THERMOMETER
Mercury in Steel

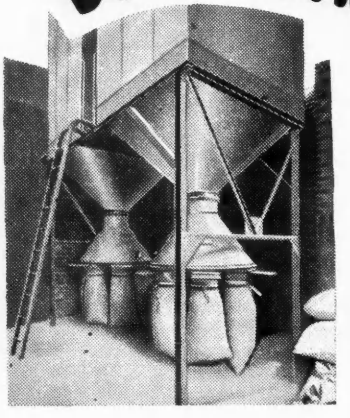
Rototherm

DIAL THERMOMETERS

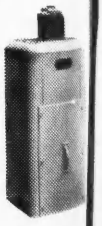
BI-METAL · MERCURY-IN-STEEL · VAPOUR PRESSURE

THE BRITISH ROTOTHERM CO. LTD.
Merton Abbey, London, S.W.19. Phone: LIBerty 7661

A "sack the lot" DUST EXTRACTION Plant



● This scheme was designed to collect the dust from a battery of wood-working machines . . . and sack it ready for sale as a by-product. It is just one of many dust extraction plants available either as units or complete installation—designed, built and installed by us—to meet Factory Act requirements and at the same time to effect working economies and to increase productivity.



- - - *also* MIDAC UNIT TYPES of DUST COLLECTION EQUIPMENT

with fabric Filter Separator (250 c.f.m. model illustrated) for such fine dusts as asbestos, tobacco, etc.—and Dynamic Type Separator models with high-efficiency cyclone, for the heavier dusts of grinding and polishing where grease is encountered. Both made in capacities from 250 c.f.m. to 2,500 c.f.m.

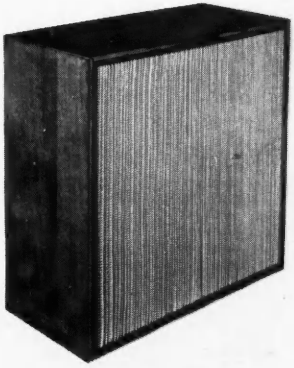
★ **For advice on any problem of dust, lint and fume collection—industrial water-cooling, etc.—'phone or write for illustrated catalogue.**

MIDLAND HEATING & VENTILATION CO. LTD.
BEDFORD RD. BIRMINGHAM. 11.
PHONE: VICtoria 0914-5

can possess the ultimate in performance characteristics, a difficulty sometimes arises in that they tend to be bulky and relatively costly. Also, metallic parts are usually involved, and in some applications, where incineration of the fouled unit is the best method of disposal, this is quite a serious objection. A search was therefore made for an alternative filter arrangement which, though perhaps not possessing the same ultimate performance as the canister, would still be more than adequate for many applications and would also have the advantage of construction from cellulosic materials, such as wood and paper, which could be readily destroyed by incineration. These requirements can now be met with the Vokes 55 Paper " Absolute " Air Filter, manufactured by Vokes Ltd., of Guildford, Surrey.

The performance of this unit has been made possible by recent developments in paper manufacture which have enabled advantage to be taken, in a compact form, of the principles employed in the high-efficiency " lap " canisters. The secret is to suspend or disperse extremely fine asbestos fibres in a matrix of relatively coarse cellulose fibres—in this case, from esparto grass. By careful control of manufacturing technique, such a composite paper can be given a remarkably high dust-retention efficiency, and yet have very low flow-restriction characteristics.

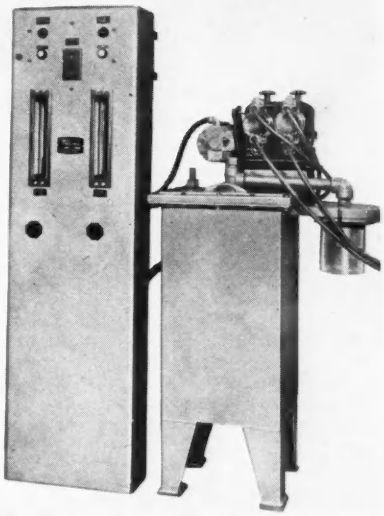
The inherent thinness of the paper permits an extremely large filtration area to be accommodated in a very small space, and it has proved possible to rate a filter panel, 24 × 24 × 11½ in. in size, at no less than 1000 cfm for an initial flow restriction of under 1·5 in. water-gauge. The shallower 24 × 24 × 5¾ in. panel has even better characteristics and is rated at 500 cfm at 1·0 in. water-gauge. Efficiency against a methylene blue or a di-octyl phthalate dust cloud is better than 99·95% initially (i.e., 0·05% penetration) and, in common with all purely " mechanical " filters, efficiency rises steadily as dust accumulates on the paper. This penetration is greater than that achieved with the " lap " canister, but is sufficiently low for most applications demanding super-efficiency filtration.



The paper, which is folded into a rectangular panel, either 24 × 24 in. or 8 × 8 in. and in alternative depths in either case, is securely cemented into a wooden frame by a special resinous adhesive which ensures freedom from leakage at the critical edge area. Each individual cell is provided with a unicellular sponge-rubber sealing pad which locates against window flanges in the main assembly framework. This system permits easy removal of contaminated panels, if necessary, without direct handling. Furthermore, as the whole unit is manufactured from combustible material, disposal of fouled filters by incineration is practicable.

SILICA ACTIVATOR

Development of their Model 63 activator for the continuous preparation and feeding of activated silica is announced by the Omega Machine Co., of Providence, Rhode Island. The " Omega " activator includes all features required for continuous silica activation and is easily adjusted to prepare the activated silica sols most effective for specific treatment conditions. Once the mixture has been prepared in a transparent mixing tank, it flows to a separate ageing tank for a controlled ageing period. The aged activated silica is then diluted for delivery to the point of application.



Some of the advantages claimed for this activator include a central control panel, for ease of operation ; the use of a continuous process, eliminating batching of activated silica sols ; and sequence starting. The unit also permits reagent selectivity in the choice of alum, chlorine, sodium bicarbonate, sulphuric acid, and ammonium sulphate ; a variation of ageing concentration and ageing time, ensuring operational flexibility ; and anti-gel interlock, which stops activant feed if the supply of raw silicate fails.

AUTOMATIC LIQUID SCALE

It has long been recognized that calculating the weight of liquids from the cubic measurement is unsatisfactory and inaccurate. The accuracy of the cubic measurement is affected by the accumulation of dirt, the presence of scum and entrained air, and the expansion and contraction of metal tanks under varying temperatures. Furthermore, the density of the liquid may vary continually, so that the factor for calculating the weight from the cubic measurement can never be accurately fixed. The Fletcher automatic liquid scale, designed by George Fletcher & Co. Ltd., of Derby, has none of these disadvantages. It continuously and automatically weighs liquids of all viscosities up to 150,000 S.S.U., and is suitable for edible liquids, chemicals, spirits, oils, hot or cold water, etc.

The device is based on the principle of tare weighing, the operating power being provided by the liquid being weighed. The scale will continue to discharge a given weight of liquid while the supply is maintained. The rate of weighing is controlled by an oil buffer which works smoothly and without shock. No balance parts are in contact with the liquid, so that corrosion and wear are negligible. Exactly the same weight of liquid is

For protection underfoot

Vickers Armstrong Ltd. install "Typrod" Mats for increased safety, improved hygiene and greater productivity. "Typrod" mats are available in standard sizes or in special sizes and shapes to order.

TYPROD MATS

Guaranteed

Awarded Good Housekeeping Institute Seal of Guarantee.

Contractors to the Ministry of Works, Ministry of Supply, etc.

Manufactured by: **TYRE PRODUCTS LTD., 303, Harrow Road, Wembley, Middx.**
Telephone: WEMbley 9555

$$\frac{d^2\theta}{dx^2}+\frac{1}{x}\frac{d\theta}{dx}-\frac{\theta}{x^2}=-\frac{V}{D}$$

$$p\left(\frac{d\theta}{dx}+\frac{1}{m}\frac{\theta}{x}\right)=M_R$$

$$n\left(\frac{\theta}{\lambda}+\frac{1}{m}\frac{d\theta}{dx}\right)=M_H$$

QUITE A SIMPLE MATTER, GENTLEMEN

And after a session with heads wrapped in wet towels, our design department will emerge triumphantly with the springs calculated to do the job better than any other. It's as well to call us in at the design stage, you know. More than thirty years facing up to this sort of thing has taught us most of the answers.

To help your design department: The Lewis Spring Co., offer a 40-page booklet on spring design, full of technical data. 2/6d. Post Free.

LEAVE IT TO
Lewis
OF REDDITCH
SPRINGS, SPRING CLIPS
PRESSWORK, WIRE FORMS
VOLUTE SPRINGS

THE LEWIS SPRING CO. LTD.

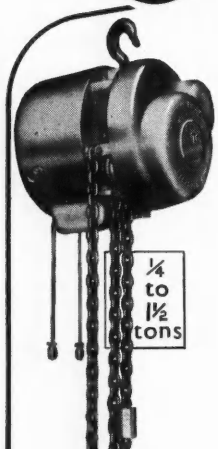
RESILIENT WORKS, REDDITCH. *Phone:* Redditch 720/1/2

London Office: 321, High Holborn, W.C.1. *Phone:* Holborn 7479 & 7470

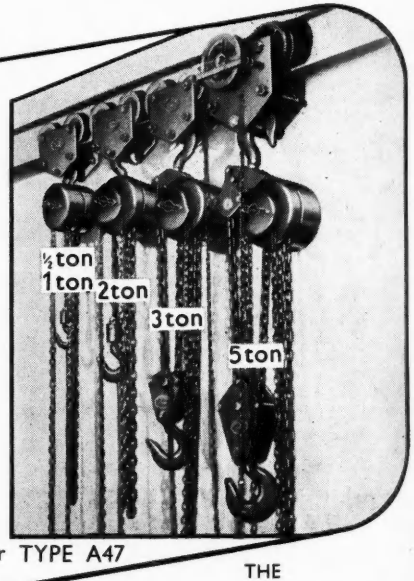
Vaughan

HOIST BLOCKS

of
High Quality
and
Fine Finish
for
Labour
Saving
Lifting

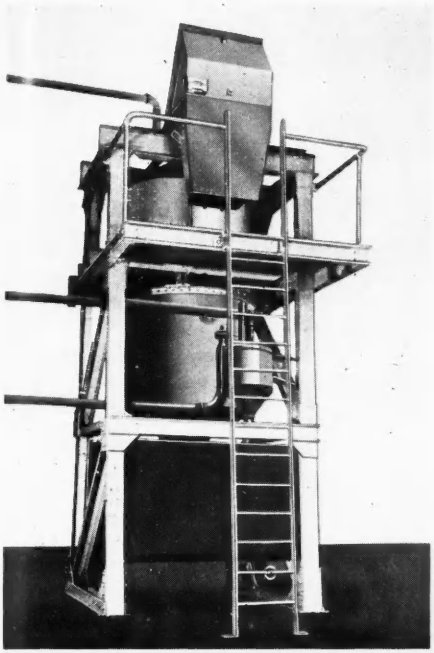


TYPE CL54 Electrically operated.



Hand power TYPE A47

THE
VAUGHAN CRANE CO. LTD.
MANCHESTER 12 : ENGLAND
Telephone: EASt 1473



discharged at every weighing and an automatic counter registers either the number of weighings or the total tonnage. The settings can be locked and any government excise seals affixed, as may be required. The highest possible accuracy of weight discharge is achieved by the self-regulation provided by the tare weight and the sharp precision with which the operations of filling and emptying the weigh tank are determined. The scale has the further advantage that it can be fitted with an automatic sampling device and also with a small tank which provides for the automatic addition of a predetermined but variable volume of secondary liquid with each discharge of the weigh tank.

These scales are built in four sizes, to deal with ½, 1, 2, and 3½ tons of liquid per tip respectively, giving a maximum capacity of 150 tons per hour of a liquid having a viscosity equal to that of water.

VACUUM-FORMING MACHINE

Stated to be the first automatic British machine of its kind, a new automatic vacuum-forming machine, designed and constructed by the Latymer Engineering Co., of London, was exhibited for the first time on the stand of Bakelite Ltd., at the B.I.F., Birmingham, where it was operated in conjunction with rigid and flexible "Vybak" P.V.C. sheet.

The new machine is extremely simple to operate, the cycle being entirely automatic, apart from placing the plastic sheet in position and removing the moulded article. An infrared blanket-type heater travels backwards and forwards automatically, the length of time it rests over the plastic sheet being determined by an electric process timer. Resting on the platen is the mould box, in which is placed the mould and over the top of which is clamped the plastic sheet. The mould box is connected, through an electrically operated valve, to a vacuum cylinder in the base of the machine. The required mould is placed in the mould box, and the two process timers, one controlling the movement of the heater, and the other the period during which the vacuum valve remains open, are set, according to the type of mould and material being used. The height of the heater can be adjusted to produce the required amount of heat directed on the sheet. The plastic sheet is then clamped in the frame, and the automatic cycle started. The heater travels forward, rests for the preset period (usually from 10 to 30 seconds, according to the thickness of the sheet) and returns to its original position. Another electrical circuit is then set in operation, and the valve into the vacuum tank opens; the air in the moulding box, below the plastic sheet, is immediately drawn into the tank, simultaneously creating a vacuum in the moulding box; the softened sheet is forced down over the mould, the valve closes, and the cycle is complete. A blast of air from an air line assists cooling of the sheet, after which the formed article is removed.

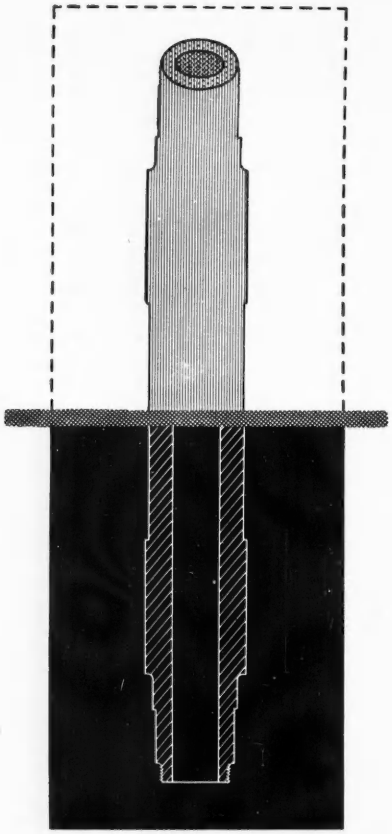
The machine has overall dimensions of 2 ft 6 in. × 5 ft × 4 ft high. The blanket-type heater, which runs on fibre rollers fitted with ball races, is 25 in. × 27 in. and has 3½ kW loading. The platen is cast in aluminium and incorporates clamping holes at 2 in. intervals, while the height between heater and platen can be varied by means of a capstan-type handwheel. An easily adjustable clamping frame for the sheet is secured by a cam-action toggle clamp and is balanced by two weights.

The pump is of the rotary type and is driven by a ½-hp motor. Evacuation is controlled by two valves—a quick-action type for thin material and the reproduction of small detail, and a slower-action type for deeper drawing and thicker material. The control panel carries pilot lamps for the heater and motor circuits, and the process timers for the heater and vacuum. When the required settings in the timers, etc., have been made, a single push-button control starts the whole cycle of operation.

CUTTER AND TOOL GRINDER

The latest addition to the range of cutter- and tool-grinding machines offered by Cincinnati Milling Machines Ltd., of Birmingham, is their No. 1 cutter and tool grinder, designed primarily for grinding and reconditioning miscellaneous small tools and cutters. It has a capacity of 8 in. swing and 15 in. between centres.

Like its companion machine, the larger No. 2, the new model has a cartridge-type grinding-wheel spindle mounting with a double row of special preloaded anti-friction bearings, packed in grease for life-time lubrication. The cartridge-type unit may be readily replaced after years of service, thus restoring new spindle performance into the machine in an interval of minutes. A reversible ½-hp motor drive, built into the wheelhead, provides the desired direction of grinding-wheel rotation, to suit any particular grinding application. Spindle speeds (6260 or 3730 rpm) are easily obtainable from a tooth-grip drive-belt and sheave arrangement.



HOLLOW BORED SHAFTS

We specialise in *deep hole drilling* in the solid bar; we have developed this process commercially over the past 25 years. The chief advantages of the hollow bored shafts made in this way are as follows:—

PRICES ARE KEEN particularly where small quantities or special sizes are required, or where the bore diameter is less than half the outside diameter.

SPECIAL PROBLEMS can be dealt with by the hollow boring method that cannot be dealt with practicably by any other process. We can for instance drill different diameter bores within one shaft, profiled if necessary to any shape required.

If you want quick delivery of hollow bored shafts—whether in stock sizes and shapes or to your own specifications—it's worth getting to know more about Keeton's. We bore any diameter hole from ¼" to 6" in lengths up to 4' in the smaller bores and up to 18' in the larger bores. Send for free leaflet.

TRADE KEETONA MARK

KEETON SONS & CO LTD

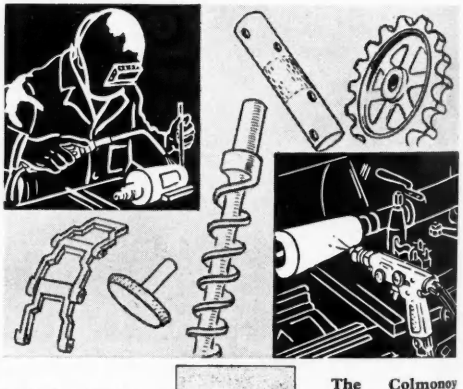
ROYDS FOUNDRY AND ENGINEERING WORKS, SHEFFIELD, 4

A MEMBER OF THE FIRTH CLEVELAND GROUP

CRC 2KH

HARD-FACING with COLMONOY ALLOYS

Colmonoy hard-facing shows the way to longer life for your equipment and machine parts. No matter the cause of wear, Colmonoy has the answer to restore worn parts and protect your new parts. You'll find protection from abrasion, corrosion and impact in its complete line of hard-facing alloys. Depending on your needs and facilities, Colmonoy is available in the form of rods, electrodes, paste, powder, metallizing wire and castings. Colmonoy is easy to apply. Any welder without special training can pick up Colmonoy and do a good job. Colmonoy reduces welding time on every job and by using lower temperatures means less chance of part distortion. You save on gas and welding current too.



Write for this Colmonoy Hard-Facing Manual. It gives a complete hard-facing guide and a table on the properties of all Colmonoy Alloys.

The Colmonoy Sprayweld Process. Powdered Colmonoy can be sprayed and then welded to the part. This process uses less material and is faster than hand-welding.

Now manufactured in our own factory in Scotland

WALL COLMONOY (CANADA) LTD

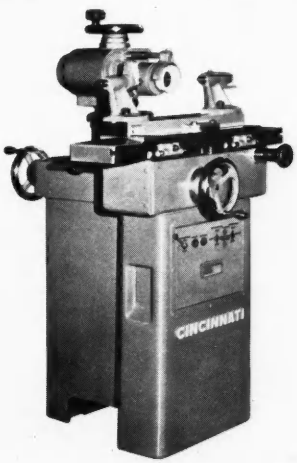
BRITISH BRANCH

CARFIN INDUSTRIAL ESTATE

LANARKSHIRE SCOTLAND

Telephone: Holytown 266

Grinding-wheel collets are quickly interchanged by removing a socket-head screw, a feature which saves wear-and-tear on the spindle. An anti-friction table slide provides unusual ease of table movement. Duplicate controls give the operator a choice of operating the machine at the front, right-hand end of the table, or at the rear, or left-hand side of the wheelhead. Curtain-type dust guards beneath each end of the table protect the anti-friction table slide and table-movement operating controls from abrasive dust. An interesting innovation is the 360-deg. eccentric wheelhead swivel. This adds 3 in. to the conventional cross range of 4½ in., facilitating surface-grinding operations and assuring ample capacity for grinding large-diameter cutters requiring the full 8-in. swing capacity of the machine. Another design innovation is the swivel-table "Tange Bar" taper-setting device. Utilizing precision gauge blocks, this device enables the operator to position the swivel table quickly and with a high degree of accuracy, thus eliminating most of the "cut and try" when grinding angular cutters and tapered reamers. Clearance-setting dials on both the workhead and left-hand tailstock permit setting for predetermined clearance angles.

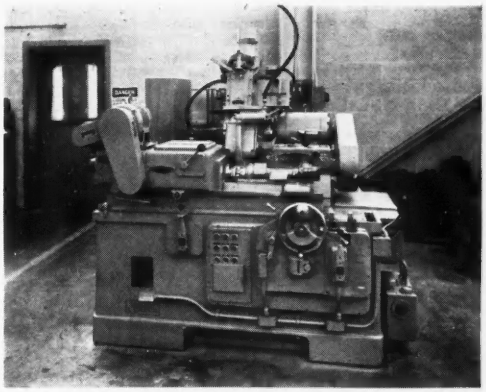


A wide variety of attachments extends the range of the machine for sharpening miscellaneous small cutters, including those of sintered carbide. Electrical controls are built in, neatly recessed in a compartment at the front of the machine. An isolating switch, operated by the latch handle on the electrical compartment door, shuts off the current when the door is opened. Built-in push-buttons are also incorporated. These consist of a start and stop button and, for machines utilizing the cylindrical grinding attachment, an additional two-way switch for the attachment motor.

PISTON GRINDER WITH SPECIAL WHEEL-FEED MECHANISM

Because of its fast, accurate action, a complete "packaged unit" for piston-grinding operations, developed by the Norton Company, of Worcester, Mass., is stated to provide real economy in the grinding of elliptical automotive and aircraft types of pistons to fine limits of size and finish. It can also be specially arranged for grinding complex skirts, where the degree of relief varies from the top to the bottom of the skirt.

The new machine is a heavily built plunge grinder with a cam generating mechanism for imparting special



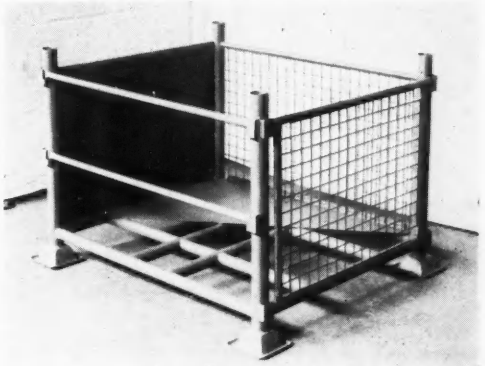
motion to the workpiece for grinding the required skirt forms. Contributing particularly to the productivity of the machine is the rapid, precise action obtained by a hydraulically actuated "revolving feed screw" wheel-feed mechanism. This provides hydraulic features for rapidly traversing the wheelhead, and a mechanical micrometer-screw feed during the grinding-feed stage to assure extreme accuracy in sizing.

Very little effort is required by the operator in running the machine, thereby permitting him to devote the major portion of his attention to loading and unloading duties. For instance, wheel truing is effected automatically by a wheel-guard type of truing device at the touch of a push-button, while the automatic grinding cycle is started by the movement of a single lever. Moreover, for speeding set-up and operation, all controls for feeds and speeds are grouped at the operating position in front of the machine. For simplifying maintenance functions, all pumps, motors, relief valves, and flow-control valves are mounted in accessible locations on the outside of the machine, while electrical controls are compactly grouped in an elevated enclosure.

TUBULAR PALLETS

A comprehensive range of tubular pallets, with all the inherent advantages of lightness, strength, rigidity, and smoothness afforded by steel tube, has been introduced by Wellington Tube Works, Ltd., of Tipton, Staffs.

In the post-pallet type, the tubular frame is particularly light and rigid, compared with other types of construction. Furthermore, the posts of post pallets can be made any desired length and can be extended by using tubes, similar in diameter to that of the posts, but reduced to fit into the post tube for a short distance.



STEEL

KEY TO INDUSTRY *No 7.*

The 16th and 17th centuries are well-known for their craftsmen in complicated locks. The key illustrated was made about 1600. You will see that 'B' fits in and over 'A', the two parts joining making a complete key and until these two parts are 'married' the key is absolutely useless. This key is a very fine example of English craftsmanship of the period.

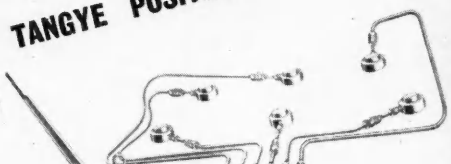
The development of steel made possible the growth of civilisation itself. For steel is the key to the good things of life as well as to the necessities; as essential to the maker of the precision watch as to the bridge-builder. Hallamshire high-grade Alloy and Carbon steels serve a multitude of industries in many ways.

Hallamsteel

Manufacturers of
ALLOY & SPECIAL CARBON STEELS · BARS · SHEETS · PLATES · WIRE RODS
THE HALLAMSHIRE STEEL & FILE CO. LTD., Sheffield, 3, England.
Telephone: Sheffield, 24304 (7 lines) *Telegrams*: Hallamsteel, Sheffield.

When installing HEAVY MACHINERY

reduce hours to minutes by using TANGYE POSITIONING JACKS



Independent control of each jack at the manifold enables their heights to be adjusted at will.

AD No. 17

TANGYE HYDRAULIC **DIVISION**

TANGYES LTD · SMETHWICK · BIRMINGHAM · ENGLAND
BRANCH HOUSES · LONDON · MANCHESTER · NEWCASTLE · GLASGOW

Send for CATALOGUE Apply on your Company letter heading.

AD. 17

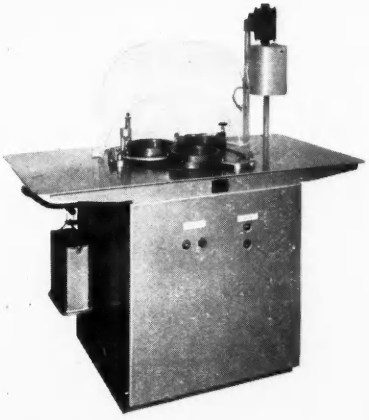
In extreme cases, the deck would be flush, and the removable posts would fit into the legs of the pallet. Other types include pallets with removable bars, removable mesh, fixed mesh, fixed sheet (box pallets), and extendable posts.

The illustration shows a pallet especially built for the recent B.I.F. to exhibit the constructional features of many of the types of pallet mentioned above.

HIGH-PERFORMANCE LAPPING MACHINE

Precision lapping to an accuracy of one light band, using unskilled personnel, is stated to be standard performance with a new self-contained lapping machine, known as the Mark IV, manufactured by Flexibox Limited, of Manchester, and designed to lap articles made in materials ranging from soft non-metals to very hard metals.

A rotary lapping plate of 21 in. diameter gives high-capacity loadings and corresponding rates, ranging from 6 per machine loading with a maximum work diameter of $3\frac{5}{8}$ in. to 99 with a maximum work diameter of $\frac{3}{4}$ in. The work to be lapped is held in three wear rings. In general, any articles which can be accommodated within a circle of $7\frac{3}{4}$ in. diameter can be lapped.

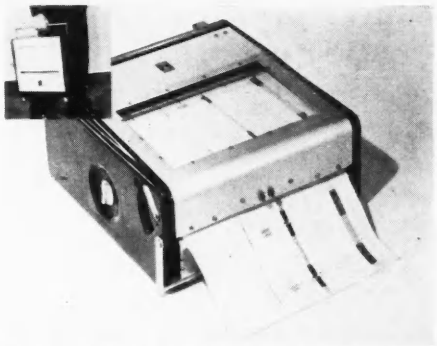


The machine is fitted with a control device which automatically maintains the flatness of the lapping plate. Only one simple adjustment of the device is necessary. Thereafter, the plate is continuously conditioned during operation. Loading and unloading are extremely simple and the workpieces are protected from dust and grime by a transparent plastic hood. Once the control device has been correctly set the machine can be operated by unskilled personnel. With reasonable care the largest of parts for which the machine is suitable can be lapped to within one light band and two micro-inches r.m.s. surface finish.

LIGHTWEIGHT 4- AND 6-CHANNEL PORTABLE OSCILLOGRAPHS

The development of two lightweight, portable oscillographs is announced by the Brush Electronics Company, of Cleveland, Ohio. These new instruments are designed for either four- or six-channel recording, the four-channel oscillograph weighing 36 lb and the six-channel recorder 48 lb. Despite their light weight and compactness, however, both models provide full-range instrumentation.

Designed for flexibility, each unit offers a range of 16 chart speeds with a travel variation of from 10 in. per day to 10 in. per second, to simplify the testing problems of electrical variables, vibration, torque,

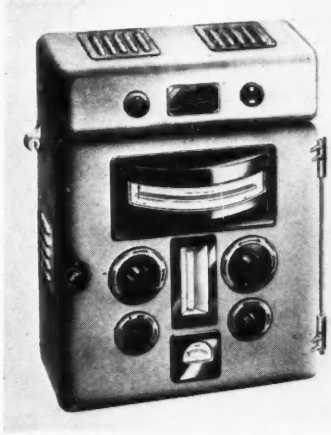


stress, strain, and other desired measurements. These models, equipped for either ink or electric writing, are claimed to be able to record a greater range of signals with optimum resolution than other direct-writing oscillographs. A control selector, which permits either a local or remote-control set-up, is incorporated in both models, while easy access to the writing table is provided through a simplified cover-removal system. Event markers are available to provide markings for any time and event correlation desired to meet any testing problem. The charts lend themselves to easy filing.

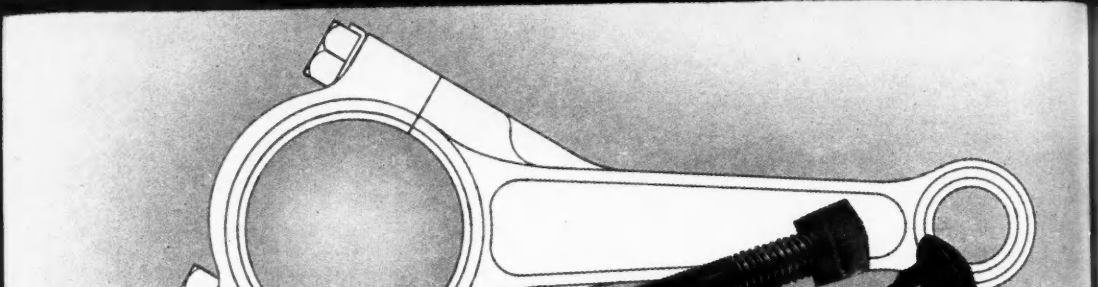
OXYGEN METER

Known as the Hersch oxygen meter, a new apparatus which can readily detect changes in oxygen concentration of half a volume per million has been developed by the Baker Platinum Division of Engelhard Industries Ltd., of London, W.C.1.

The meter will continuously measure traces of oxygen present as an impurity in other gases and, although it fulfills much the same function as the existing " Deoxo " indicator, it is very much more sensitive and covers the range from 0 to 100 volumes per million. At maximum sensitivity, the full-scale deflection on the 10-in. scale of the meter represents 10 volumes per million, so that changes in oxygen concentration of only 0·5 vpm can be readily detected. The accuracy of the indication is claimed to be less than $\pm$ 5% of full-scale deflection, while the response of the instrument to changes in oxygen concentration is almost instantaneous.



The meter, which measures approximately 18 in. $\times$ 12 in. $\times$ 24 in. high, should be useful in many metallurgical and chemical processes where the maintenance of an oxygen-free atmosphere is essential.



TWO WAYS OF INCREASING LOAD CAPACITY

OR

"You wouldn't put coach bolts in your big ends!"

ONE WAY of increasing bearing capacity, of course, is to use a bigger bearing. The other way is to add more refinement. It doesn't look noticeably different on the drawing or on the assembly bench, for it consists of putting a higher quality into the same size of bearing.

BUT THE DIFFERENCE IS OUTSTANDING

F.B.C. bearings evolved for high-duty aircraft applications have raised the bearing performance to an almost unbelievable figure, by their high-precision, extra quality and detail development in relation to the ball location and contact.

In the light of present day knowledge, therefore, to use an 'ordinary' catalogued ball-bearing for a border-line high-duty job is as near to sabotage as putting M.S. bolts into a racing-car big-end.

F.B.C. :: FISCHER TRADE MARK

ALL-BRITISH
BALL AND PARALLEL-ROLLER BEARINGS

FISCHER BEARINGS CO. LTD., WOLVERHAMPTON

FISCHER BEARINGS COMPANY LTD. and TIMKEN-FISCHER STOCKISTS LTD., BIRMINGHAM, are both subsidiaries of BRITISH TIMKEN LTD.

MAGNETIC-TAPE RECORDER FOR AIRBORNE TEST DATA

A highly accurate, portable magnetic-tape recording system for the airborne collection of test data has been developed by the Consolidated Engineering Corporation, of Pasadena, California. Designated "Datatape," the system will perform under extremely adverse environmental conditions and permits simultaneous recording of large quantities of data during a single flight. Furthermore, it will operate unattended aboard aircraft and guided missiles at distances well beyond the effective range of telemetering equipment.

The system, packaged in individual, compact, modular units, includes a recorder, amplifiers and modulators, a calibrator, a time-code generator, and a remote-control power supply. A playback unit which re-creates the flight performance data in electrical form for ground analysis and computation has been developed as part of the system. In the illustration, the recorder is shown at the top, and the amplifier, which is attached to a shock-mount, at the bottom.

The recorder unit is designed to store 28 tracks of information on 1¼-in. tape, providing 24 data channels and 4 auxiliary channels, including a microphone input. It has a tape capacity for 43 minutes of recording at a speed of 10 inches per second, when using tape of conventional thickness. Playing time can be extended to 70 minutes or longer by using thinner tapes and by reducing tape speed to 7½ inches per second or less. The recording system operates with less than 1% error, using pulse-duration modulation (PDM) or compound modulation (CM). Error is less than 3% when using wide-band frequency modulation (FM). The recorder detects its own malfunctioning. A single-track data-monitor head readily detects such mechanical failures as broken tape, improper tracking, failure of the pinch-rolls to close, failure of uniform tape motion, or the end of the tape. Electronic failure is also readily detected. In any of the above situations, an indicator light warns the operator at local and remote control stations.

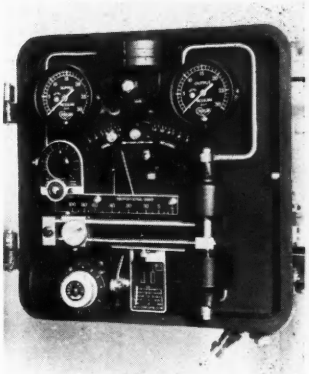
One of the unique design features of the tape transport is a rigid cast assembly, accurately machined, on which are mounted the capstan and all other precision elements in the tape-feed path. The precision assembly is, in turn, shock-mounted to the top plate of the recorder. This type of construction minimizes tolerance build-up and avoids warpage problems, so common in conventional top-plate designs. In addition, it provides much improved isolation of the capstan assembly from high-frequency vibration.

The following performance figures were obtained on the prototype recorder at a tape speed of 10 inches per second :—Low-frequency flutter has been consistently measured at 0·1% peak-to-peak or less ; high-frequency flutter (above 100 cps) varies from 0·2% to 0·35% peak-to-peak ; total peak-to-peak flutter may be expected to be under 0·4%, measured with a 3500-cps pass-band discriminator.

Data collection and processing are simple :— Physical parameters such as stress, pressure, acceleration, vibration, or temperature are converted into electrical analogue signals by conventional transducers, such as strain gauges and variable-reluctance units, velocity pick-ups, or thermocouples ; the signals are amplified, modulated, and recorded on magnetic tape ; the tape is removed from the recorder and placed on the playback unit ; and the electrical signals recovered from the tape may then be converted into digital form at high speed, using an analogue-to-digital conversion system.

AIR-OPERATED DISPLACEMENT-TYPE LIQUID-LEVEL CONTROLLER/ TRANSMITTER

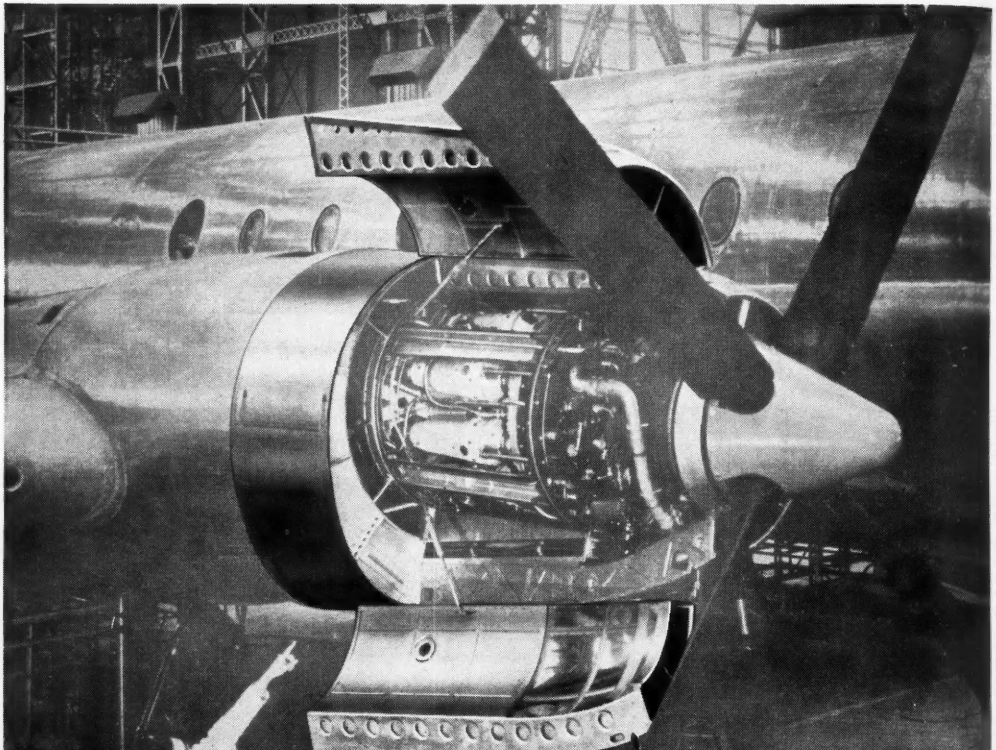
The new Mason-Neilan Series 12800, air-operated displacement-type liquid-level controller/transmitter, manufactured by The Crosby Valve & Engineering Co. Ltd., of Wembley, supersedes their Series 12600 level controller, and, whilst the fundamental principles are the same, the new instrument incorporates many additions and improvements.



The pneumatic control mechanism is mounted directly on a cast-iron frame, which itself is bolted to the torque-tube housing, thus eliminating the possibility of any control offset due to mishandling of the instrument case. The specific-gravity adjustment scale, which enables the instrument to be set for the density of the liquid being controlled, has been widened to a range of 0·5 to 1·4, thereby serving most applications with one scale. The set-point scale has been considerably increased in length, the method of adjustment is simplified, and it is so arranged that a 3 to 15 psi bellows for remotely setting the control point can easily be provided. A new and improved reset or integral-action resistance unit can readily be fitted to a standard proportional controller on site. The size of the torque-tube mechanism chamber has been reduced, thus saving considerable weight and space. The dimensions between connection centres now conform with international standards. The new pilot valve uses slack diaphragms of special materials for sensitivity and long life, and incorporates a jewel orifice fitted with a plunger to enable this orifice to be cleaned whilst the instrument is in operation. The method of setting the accurately calibrated proportional band has been improved to facilitate setting and locking.

The controller is available for mounting with the displacer either inside or external to the vessel concerned, and can be supplied as a proportional controller with or without reset, as a transmitter, as a specific-gravity transmitter or controller, or as a combined controller and transmitter.

We shape the things to come



"THE BRITANNIA"

Manufacturers of the prototype main engine cowling and of the production line rear engine cowling, door assemblies, oil systems and oil cooler mounting panels.

THE ABBEY PANEL & SHEET METAL CO. LTD.

OLD CHURCH RD., LITTLE HEATH, COVENTRY

EXPERTS IN HIGH CLASS SHAPE PANEL WORK
AIRCRAFT AND AUTOMOBILE FABRICATIONS AND ASSEMBLIES

Telephone Nos. : COV. 89461 - BEDWORTH 2321

A.I.D. & A.R.B. Approved

NEWS OF THE MONTH

PERSONAL

Mr. J. S. Abbott has been elected to the Boards of Glenfield & Kennedy Ltd., and Glenfield & Kennedy (Holdings) Ltd.

Mr. E. W. Barrell, M.I.Prod.E., has been appointed works manager of Churchill-Redman Ltd., Scotswood Division, Newcastle-on-Tyne.

Dr. J. W. Barrett has been elected a director of Monsanto Chemicals Ltd. and will continue his present responsibilities for the company's research and development activities.

Mr. F. W. Bates, works director of Kelvin & Hughes Ltd., the parent company, **Mr. R. W. Dunn, B.A., A.R.Ae.S., F.I.P., M.I.N.** chief engineer (Aviation Instruments), **Mr. D. H. Perkins, M.B.E.,** works manager at the Kelvin Hughes Works, Basingstoke, and **Mr. G. Wikkenhauser, M.B.E.,** chief engineer at the Barkingside factory, have been elected to the Board of Kelvin & Hughes (Aviation) Ltd. **Mr. P. J. A. Turner,** chief engineer at the Glasgow factory has been elected a director of Kelvin & Hughes (Industrial) Ltd. **Mr. H. R. Whitfield,** chief radar engineer, and **Mr. R. M. Stephenson,** overseas sales manager, have been elected to the Board of Kelvin & Hughes (Marine) Ltd.

Mr. R. W. Burchhardt, technical manager of Colloidal Graphite Ltd., 6/7 St. Dunstan's Lane, London E.C.3, has been elected to the Board.

Mr. H. H. Daker, B.Sc., A.M.I.E.E., C.P.A., has been appointed patents officer to British Insulated Callender's Cables Ltd.

Mr. H. H. Eggers has been appointed a managing director of Cable and Wireless Ltd. to serve jointly with Mr. N. C. Chapling.

Mr. B. Eichler has been appointed director of research of the Silica and Aluminous Division of General Refractories Ltd., and **Mr. H. Parnham** has been appointed director of research of the Basic Division at the General Refractories Group Central Research Laboratories at Worksop.

Mr. Percy Evans has been appointed home sales manager of Brush Electrical Engineering Co. Ltd., Loughborough, and retains his position of sales director of Hopkinson Electric Co. Ltd., Cardiff.

Mr. W. W. Franklin, M.I.Mech.E., chief engineer and a director of Davy and United Engineering Co. Ltd., Park Iron Works, Sheffield 4, has been appointed technical director. **Mr. J. B. Bucher, Dipl.Ing., A.M.I.Mech.E.,** has been appointed chief engineer.

Rear-Admiral J. G. C. Given, of the Engineering Branch, Royal Navy, has been elected a director of Parsons Marine Steam Turbine Co. Ltd., Wallsend-on-Tyne. On the retirement of **Mr. A. Hopper,** at the end of this year, Rear-Admiral Given will assume the position of managing director of the company.

Mr. Reginald H. Hemmens has joined The Sheffield Twist Drill & Steel Co. Ltd. as London office manager. He will operate from the company's London office at Terminal House, Lower Belgrave Street, S.W.1.

Mr. D. H. Leeson, M.A.(Cantab.), A.M.I.E.E., G.I.Mech.E., has joined Crompton Parkinson Ltd. as home sales manager of their associate switch-gear concern, Cooke & Ferguson Ltd., Manchester.

Mr. C. G. F. Pritchett, M.I.E.E., A.C.G.I., a director of Chloride Batteries Ltd., Exide Works, Clifton Junction, Swinton, Manchester, since May, 1952, has assumed the position of chief engineer of the company, in succession to the late **Mr. C. P. Lockton**

Mr. R. J. Pycock, until recently chief production engineer at Hoover's High Wycombe factory, has been appointed technical superintendent of the Australian factory, Hoover (Industries) Pty. Ltd., Meadowbank, Sydney. **Mr. D. Hamlyn** has been appointed chief production engineer, to succeed Mr. Pycock, at High Wycombe, Bucks.

Mr. H. R. Rowbotham has been elected chairman of Joshua Bigwood & Son Ltd. and will retain his office as managing director of the company.

Mr. E. R. Sisson, A.R.Ae.S., has been appointed technical service manager to Smiths Aircraft Instruments Ltd., London, N.W.2.

Mr. C. D. P. Smallpeice, chairman, **Mr. G. Godwin, Mr. R. C. Cartwright,** and **Mr. C. Kirk,** technical director, have been elected to the Board of Martonair Ltd., Parkshot, Richmond, Surrey.

Mr. C. Stephenson, general manager of Hawthorn Leslie (Shipbuilders) Ltd., and **Mr. C. N. Storey,** secretary, have been elected directors of the parent company, R. & W. Hawthorn, Leslie & Co. Ltd., St. Peter's Works, Newcastle-on-Tyne 6, and its subsidiary companies. **Mr. D. G. Ogilvie,** general manager, has been elected to the Board of Hawthorn Leslie (Engineers) Ltd.

Mr. J. M. Waldram, senior research illuminating engineer of the General Electric Co. Ltd., has been elected President of the Association of Public Lighting Engineers.

Mr. T. Watson, director of General Refractories Ltd., Sheffield, has been elected President of the Refractories Association of Great Britain.

Mr. R. E. G. Weddell, joint managing director of W. G. Allen & Sons (Tipton) Ltd., has been elected President of the Institute of Welding. **Sir Charles Lillicrap, K.C.B., M.B.E., D.Sc.(Eng.),** former Director of Naval Construction, has been elected vice-president.

HYDRO-ELECTRIC DEVELOPMENT IN NORTHERN IRELAND

To develop the natural resources of power in the waters of the River Mourne and its tributaries, now used on a small scale for the generation of electricity in a private station, and to use it to generate electricity which can be distributed by the general mains system, the Northern Ireland Ministry of Commerce has introduced a hydro-electric scheme which will cost £3,750,000.

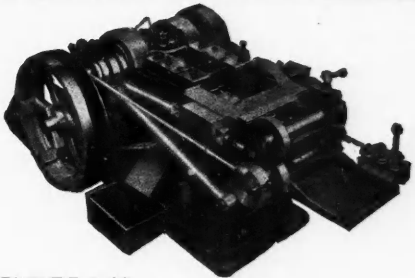
It provides for the construction (a) of a dam with a hydro-electricity generating station (having a capacity of 18,000 kw) near Mulvin on the River Mourne and (b) of a dam with a hydro-electricity generating station (having a capacity of 9,500 kw) near Sion Mills on the same river.

The scheme also provides for the electrical inter-connection of the stations and for their connection with existing power sources. Copies of the scheme and of an explanatory note will be available for inspection until 23rd July at local authority offices in County Tyrone, at the Belfast, Omagh and Strabane offices of the Electricity Board for Northern Ireland and at the Ministry of Commerce, Chichester House, Chichester Street, Belfast.

NEW £3.6 MILLION STEEL STRIP ROLLING MILL

On the site of an old Roman camp at Templeborough, near Rotherham, Steel, Peech & Tozer, a branch of The United Steel Companies Ltd., are to build a large new steel rolling mill. It will cost about £3.6 million and will produce thin steel strip up to 18-in. wide. Initially, it will produce about 3,000 tons of steel strip each week, increasing gradually to 6,000 tons weekly.

The mill, which is intended to bridge the gap between the



"CEVA" TRIPLE BLOW COLD FORGING PRESSES FOR BOLTMAKING

Model	Thread Diameter approx.	Max. Length	Production per hour	H.P. Reqd.	Weight lb.
F53	$\frac{5}{32}$" to $\frac{1}{4}$"	$\frac{7}{16}$" to 2$\frac{3}{8}$"	3,000 to 5,000, according to size	10	9,200
F54	2 mm to $\frac{3}{16}$"	$\frac{5}{16}$" to 1$\frac{1}{4}$"	5,400 to 6,000	5	5,950
F55	$\frac{5}{16}$" to $\frac{1}{2}$"	$\frac{13}{16}$" to 4$\frac{1}{4}$"	2,400 to 3,000	15	22,000

These machines, which operate in three stations in line, are designed on the most modern principles. They combine great rigidity with carefully selected materials, high standards of workmanship and assembly, and are subjected to the most rigid tests before approval.

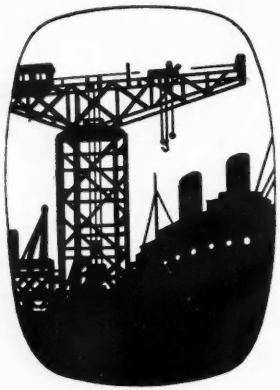
Machine frames are constructed of cast iron or steel, in accordance with clients' requirements, are liberally dimensioned, and are capable of withstanding any stresses set up during work.

Shafts, cams, and all components subjected to dynamic forces are made of hardened and ground steel. Heavy gears are of cast steel.

Feeding of the workpieces to the individual dies is accomplished by means of grips operated by a special mechanism of simple and efficient design, which allows the feeding in of short blanks.

General Overseas Agents:

S.I.T.A.—Società Italiana Trafilati Acciai,
Via Conca del Naviglio, 2, Milan, Italy.



Covers the entire engineering industry

When the next Engineering Marine & Welding Exhibition and the Foundry Trades' Exhibition takes place at Olympia, in September, 1955, it will be 49 years since this important event was inaugurated. Since then the Exhibition has grown in size and prestige until it is now recognised by buyers of plant and equipment as the most important event in the Engineering Calendar.

The wide scope of this Exhibition is indicated by the fact that over 500 exhibitors are displaying their products under 800 classifications. Make a note of the date now—

Organisers :
F. W. BRIDGES & SONS LTD.
Grand Buildings,
Trafalgar Square,
London, W.C.2
Telephone: WHitehall 0568/9

ENGINEERING MARINE & WELDING EXHIBITION AND THE FOUNDRY TRADES' EXHIBITION

September 1st to 15th, 1955
OLYMPIA · LONDON

OPTIQUE DE PRÉCISION DE LEVALLOIS

— SERVICE COMMERCIAL : **10 rue Auber, PARIS (9e)** —

O.P.L. MICROMETRIC INSPECTION DEVICE

An indispensable part of a milling, boring or drilling machine. The micrometric inspection device easily maintains a machining accuracy of the order of 1/100mm. Mounted on a precision machine tool, it not only makes it possible to increase the efficiency of the machine, but better still, ensures remarkable consistency in the quality of the work.

OTHER INSTRUMENTS :

OPTICAL DIVIDING HEADS — CENTERING MICROSCOPES — BENCH PROJECTORS — GRINDING GONIOMETER — GONIODRILL — ALIGNING AND MEASURING TELESCOPES — UNIVERSAL PHOTOMICROSCOPES, ETC.

O P L

output of the narrow and wide strip mills at present operating in this country, is being supplied by the Loewy Engineering Co. Ltd. It is being designed to produce strip from 4-in. to 18-in. wide with a maximum thickness of ¼-in. down to .042-in. minimum in deep drawing, mild, medium carbon, razor and stainless qualities.

The mill will be equipped throughout with electric screw-down gear and four high-pressure water descaling stations will be situated at various points in the train. Fabric bearings are being adopted on the roughing train, with roller bearings on the finishing train. All the main electrical equipment for the mill, including the motor drives, is being supplied by the English Electric Co. Ltd. All auxiliary d.c. motors, up to and including 150 hp, are being supplied by Metropolitan-Vickers Electrical Co. Ltd.

S.B.A.C. DISPLAY 1955

The Society of British Aircraft Constructors will stage its 16th Flying Display and Static Exhibition in September this year and, once again, The Royal Aircraft Establishment, Farnborough, will become for one week the focal point of the aviation world.

There are other air displays in the world, some of them international in scope. Yet not one compares with the S.B.A.C. Air Display in size, number of exhibits, and showmanship. The Society's experience in organizing and running flying Displays is unrivalled, having staged no less than 57 separate air shows since 1932. In 1948 when the Display was first held at Farnborough, seven complete displays were given in seven days. Since then very nearly 1½ million spectators have paid to see these shows on the public days, all of which repeated the unique programme of 1948.

The 1955 Air Display will be the biggest and best ever. A record number of more than 300 exhibitors (compared with 292 in 1954) will display their products to the expectant eyes of the world, while the area of the exhibition will represent an increase of nearly 12 per cent. over last year's record figure of 100,800 sq ft. In 1954 an 85-page booklet listed as briefly as possible the exhibits on view—this year, the booklet will be larger, and will include items ranging from complete aircraft to anchor nuts, helicopters to hacksaw blades, jet engines to Gee radar equipment, nuts and bolts, tubing, asbestos, tools—indeed, an almost infinite selection of aeronautical components.

BUSINESS NOTES

North West Machine Design Co. Ltd. have moved to new offices at 177 Kenton Road, Kenton, Harrow, Middlesex. Tel. No.: WORdsworth 0301/3.

The Plessey Co. Ltd., Ilford, Essex, has formed a new company, the Amar Tool and Gauge Co. Ltd., Chadwell Heath, Essex, which has taken over production of standard tools and gauges, interchangeable pillar type press tool sets, drill jigs and other equipment formerly manufactured by Plessey's Tools and Gauge Division. Mr. J. R. Thomas, a director of the new company, will be responsible for sales development.

Holman Brothers Ltd., have formed a new subsidiary company, Dustuctor Co. Ltd., Hayle, Cornwall. Mr. A. T. Holman is chairman, Mr. F. F. L. Morgan, general manager, and Mr. E. B. James, development engineer of the new company.

Fibromold Ltd., a new company has been formed at Old Manor Cottage, Sand Marsh, Ripley, Surrey, to produce resin laminated glass structures. The firm has taken a factory at Hanworth Lane, Chertsey. Mr. Roy Siemssen is chairman, and Mr. Charles Meisl, managing director of the company.

Wickman Ltd., Banner Lane, Tile Hill, Coventry, have acquired all the issued ordinary capital of Arthur Scrivener Ltd., machine tool manufacturers, Tyburn Road, Birmingham.

Burton, Griffiths & Co. Ltd. have moved their Glasgow office to 135 Wellington Street, Glasgow C.2. Tel. No.: Central 0021/2. The Branch remains under the management of Mr. J. S. Cochrane.

Wolf Sales Pty. Ltd., 122-124 Sussex Street, Sydney, Australia, has been formed by Wolf Electric Tools Ltd., as a sales organization for Wolf Electric tools. Mr. D. K. Nicholas is chairman, and Mr. C. F. Macdonald, managing director of the company, whose Board includes Mr. R. F. Hatto, sales director of the manufacturing company.

Skil Engineers Ltd., Reynold Works, Chell Street, Longsight, Manchester 12, is the name of the new company which has been formed for the manufacture and sale of MRE profile turning roller box and radius attachment. These will be marketed in the future under the trade name of "Skil." Mr. H. Livingstone is managing director of the company.

Permali Ltd., Gloucester, have now finalized plans for setting up a factory in the U.S.A. The new factory will be built at Mount Pleasant, near Pittsburgh, and production is expected to begin by the end of this year. The present address of the American subsidiary, Permali, Inc., is 55 West 42nd Street, New York, N.Y.

The General Electric Co. Ltd., is transferring production of radio receivers from its Spon Street Works to another factory in Coventry, and is devoting to television production the whole of the manufacturing space previously occupied by domestic radio production.

The new and enlarged facilities for television production include flow line assembly tracks which embody "soak" testing facilities during the various stages of manufacture. Potential output will be increased by more than 50 per cent.

Wickman Ltd., Banner Lane, Tile Hill, Coventry, have concluded arrangements for the sole representation in the U.K. of Eumuco A.G. für Maschinenbau, Leverkusen, Germany, manufacturers of hydraulic and mechanical forging machines, and Nagel Maschinen-und Werkzeugfabrik G.m.b.H., Nürtingen, Württ., Germany, manufacturers of vertical and horizontal honing machines, super-finishing machines for brake drums and super-finishing spindles.

G. W. B. Furnaces Ltd., jointly controlled by Gibbons Brothers Ltd., Dudley and Wild-Barfield Electric Furnaces Ltd., Watford, have decided to build a factory for the manufacture of electric control gear at Bangor, Co. Down, Northern Ireland.

Easterbrook Allcard & Co. Ltd., Sheffield 6, have opened a new office and warehouse at East India House, Helena Street, Parade, Birmingham 1. Tel. No.: Central 6997. Mr. P. E. Pickering has been appointed Midlands sales representative of the company.

Flexello Castors (Export) Ltd., Bath Road, Slough, a new separate export company has been formed to deal exclusively with the rapidly expanding export business in Flexello castors and wheels for industrial, domestic and institutional purposes.

The Magnetic Equipment Co. Ltd., Lake Works, Portchester, Hants, are now represented in Holland by Berg & Burg, De Ruyterkade 141/2, Amsterdam, in Belgium by Willy Depireux, Rue Hector Denis 74, Mont-sur-Marchienne, Charleroi, and in Eire by the Modern Plant and Appliance Co., 64 Aungier Street, Dublin.

Albert Mann's Engineering Co. Ltd., Basildon Industrial Estate, Essex, have concluded an agreement with American manufacturers of rolling mill equipment to manufacture the "Stanat" machines in Great Britain. The equipment will be known as "Stanat-Mann" 2-high/4-high combination rolling mills. The 1½-in. and 5-in. by 8-in. and the 2½-in. and 8-in. by 8-in. sizes are already available. Designed to accomplish the work of two or more mills, these new heavy-duty machines can be used for bar, rod and strip reduction.

Commonwealth Welding Conference. The Council of the Institute of Welding has decided to hold a Commonwealth Welding Conference in London in the summer of 1957. The objects of the Conference will be :—

(1) to promote an exchange of information on the present technical position of welding processes and their main applications within the British Commonwealth ;

(2) to consider means of improving the exchange of technical information among the countries of the Commonwealth.

It is intended that the Conference should be open to all who are interested in welding ; invitations to appoint official delegates will

We go for the little jobs in a big way!
As one of the largest specialists in the design and manufacture of small electric motors, we have the resources which usually enable us to provide the best solution to any problem in this field. It will pay to consult us first!
Illus.: Type 335C40 Geared Motor, with A.C. & D.C. interchangeable frames. 1-20 r.p.m. Torque: 20-10 lbs. ins.
There's a FRACMO for your job!

The very wide range of **"FRAMCO"** *Motors include:* **UNIVERSAL** 1/250 to ¼ h.p. ● **SINGLE, SPLIT PHASE** 1/80 to 1/6 h.p. & **CAPACITOR** 1/100 to ¼ h.p. ● **3-PHASE** 1/20 to 1/3 h.p. **SYNCHRONOUS** 1/100 to 1/16 h.p. ● **SHADED POLE** 1/160 h.p. at 1300 r.p.m. ● **GEARED UNITS** 0.25 to 600 r.p.m. Torque up to 800 lbs. ins.

FRACTIONAL H.P. MOTORS LIMITED

Rookery Way, Hendon, N.W.9 Tel. Colindale 8022/3/4

Our Birmingham address is :

6 Lansdowne Road, Erdington, Birmingham 24 Tel. Erdington 0460

HALLMAC TOOLS

Head Office and Factory
—one of four Depots

A New SERVICE THAT SOLVES TOOL SUPPLY PROBLEM!

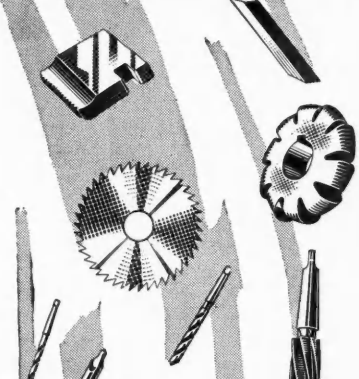
Have you still to experience the advantages of obtaining practically all your requirements in Engineers' Small Tools and Sundries from Hallmac?

This recently formed Organisation has set a new standard in efficiency, with on-time delivery from a large and comprehensive stock range comprised of only the finest tools.

All four Hallmac Depots carry stocks and are strategically placed. Hallmac Representatives are linked throughout the country—Hallmac is ready and waiting to serve you.

Write for latest literature on

tools from HALLMAC



HALLMAC TOOLS
LIMITED

Head Office and Depot: G.P.O. Box 39, Macrome Road, Wolverhampton. *Telephone* 52001 (5 *lines*).
Also Depots at London, Manchester, Glasgow.

DISTRIBUTORS OF ENGINEERS' SMALL TOOLS
Macrome Treated Tools · Hand and Power Tools

JW.Ad 3612.

be addressed to the welding societies and Government departments of the Dominions and Commonwealth territories. An organising committee has been appointed under the Chairmanship of Mr. A. Robert Jenkins, J.P., M.I.Mech.E., and further announcements will be made from time to time.

Permali Limited, have registered two new subsidiary companies. Hydulignum-Jabroc (Tools) Ltd., Hydulignum Works, Haddenham, Bucks, and Mill Lane, Waddon, Croydon, Surrey, will combine the tooling businesses in laminated densified wood, metal and other materials formerly conducted by Hordern-Richmond Ltd., as a subsidiary of Permali Ltd., and Jablo Plastics Industries and Moulded Components (Jablo) Ltd. The re-equipment and extension of the Croydon Works now proceeding will provide a substantial increase to existing capacity.

The directors are Mr. A. A. Heath, M.A., M.I.E.E., Mr. J. H. Collins, B.Sc., F.R.I.C., Mr. B. Jablonsky, A.F.R., Ae.S., The Rt. Hon. Lord Selsdon, D.S.C., and Mr. J. Watson, F.C.I.S.

Jabroc Ltd., Mill Lane, Waddon, Croydon, Surrey, will continue the manufacture of "Jabroc" densified wood laminates, strictly in accordance with existing manufacturing specifications. Arrangements have been made for the completion of all open contracts placed with Jablo Plastics Industries and Moulded Components (Jablo) Ltd., and for the future sale of "Jabroc" material. The Board consists of Mr. H. Howarth, Mr. J. H. Collins, B.Sc., F.R.I.C., Mr. B. Jablonsky, A.F.R.Ae.S., and The Rt. Hon. Lord Selsdon, D.S.C.

The management of both companies is under the direction of Mr. J. H. Collins, B.Sc., F.R.I.C.

Manchester Repetition Engineers Ltd., Alexander Street, Hyde, Cheshire, announce that consequent upon a reconstruction of the Company, they are now concentrating solely upon the development of their already well known Centering and Centering and Spot Facing Machines.

Special attention is being paid to the development of the 1½-in. capacity machine which incorporates the patent interchangeable cones secured into the work-supporting arm and which obviates the necessity of holding the workpiece.

CONTRACTS

A further order of 200 megawatt steam turbo-alternators has been awarded on competitive tender to **The English Electric Co. Ltd.** by the Central Electricity Authority. This makes a total of three such machines to be built by the company for the Authority.

The machines, which will be built at the English Electric Rugby works, are to be installed in the new power station to be built, subject to Ministerial consent, at High Marnham on the River Trent. When it is completed High Marnham will be the largest power station in the country with a total installed capacity of one million kilowatts or over one and one-third million horse power, generated by five 200 megawatt turbo-alternators.

The machines will be the largest ever manufactured in Britain, and the biggest of their type in Europe. Nearly twice as powerful as the largest units already in service in Britain, a single machine will have a higher output than most of the complete power stations now in commission.

It will, for example, be capable of contributing to the National Grid System as much current as is used domestically by about four million people. In addition, the increased efficiency of these large sets will mean that, for the same amount of coal, almost 10 per cent. more electricity will be generated than the present average obtained from existing power stations.

An interesting and important order for rolling mill plant has been received recently by **British Thomson-Houston Co. Ltd.** to replace one of their older machines which has already done 36 years service. In 1919 BTH supplied to Steel, Peech & Tozer, of Sheffield, a 6000-hp Reversing Cogging Mill drive. The mill driven by this motor has been one of the busiest in the country and has broken many records for output. Some years ago it was completely modernised but the old BTH drive was retained. During its long service this drive has been working 24 hours a day, 5½ days a week, on the most arduous duty and is still going strong.

The mill owners—however, conscious that equipment cannot be expected to stand up for ever to such arduous duties and recognizing that a major breakdown would be a disaster—have decided to replace the old by a completely new drive. After careful consideration it was decided to increase the horsepower to 7,000 to cater for still greater mill demands to be expected in the future. BTH engineers, fully exploiting improved designs developed since 1919, have been able to offer a motor of the required 16½ per cent. larger rating to go on the existing baseplate: this will be a great advantage in shortening installation time at the changeover. The full rating of the new motor is 7,000 hp, 50/100 rpm, 1,500 volts, with a cut-out rating of 21,000 hp. The motor-generator set being supplied with it has a 5000-hp induction motor, three 1867-kW, 500-volt generators, and a 30-ton flywheel.

The control gear, of the latest BTH design, will be capable of very high rates of reversal. For instance, it will be possible to reverse the mill motor, the armature of which weighs 100 tons, from 50 rpm in one direction, to 50 rpm in the other direction in 1½ seconds. In service it will have to do this about ten times a minute, day and night continuously; which means that 100 tons will be reversed in direction on an average every 6 seconds.

Sheepbridge Equipment Ltd., have received an initial order for Sheepbridge mine cars from the National Coal Board for the Cynheidre New Colliery in the South-Western Division.

Cynheidre New Colliery is a new project and part of the large organisation scheme for the Welsh Coalfields. It is understood that the total requirement of mine cars will be between 2,000 and 3,000.

The Fraser & Chalmers Engineering Works of The General Electric Co. Ltd. have received an order from the Silvermines Lead & Zinc Company Limited of Eire to supply a heavy media separation plant. This equipment is intended to double the tonnage of lead/barytes ore to be treated without the need for further extension to the existing flotation plant. A 7 ft diameter separatory cone will be employed, using ferro-silicon medium. All motors and starters will be manufactured by the G.E.C.

British Insulated Callender's Construction Company Ltd. announce the receipt of an order from the Central Electricity Authority for the erection of a further 92-mile length of the 275,000-volt Supergrid between Hams Hall, Birmingham and Melksham in Wiltshire. The work is due for completion by October 1956.

John Thompson Limited, Wolverhampton, has been entrusted by the United Kingdom Atomic Energy Authority (Industrial Group) with a major engineering contract in connection with the Dounreay Nuclear Power Station.

Dounreay Station, as announced in the Government White Paper, "A Programme of Nuclear Power," February 1955, is the first "fast breeder" reactor to be built in the United Kingdom as a full scale experimental model capable of producing power.

The work entrusted to John Thompson Limited, involves the development in collaboration with the United Kingdom Atomic Energy Authority of methods of fabrication for the liquid metal circuits, the design of complete steam and water equipment, the manufacture of the whole of the fusion-welded stainless steel vessels, liquid metal pipe lines, primary and secondary heat exchangers, boiler drums and of the associated plant, valves and instrumentation, together with the feed water treatment plant. The company has developed a separate department to deal with this contract, and manufacture has commenced.

It was stated in the White Paper that the Dounreay Station was to be built to produce data and experience for the further development of fast reactor Stations in order to obtain a large positive "gain factor" in the breeding of plutonium. Because of this positive "gain factor," i.e. the production of more fissile material than is consumed, the eventual Commercial Stations of the "fast-breeder" type will provide a better utilisation of the Nuclear fuel than any of the earlier gas-cooled or liquid-cooled thermal reactors which it is proposed to build.

Many difficult technical problems arise, however, in the development of the fast reactor. The reactor operates without the moderator used in the type being built at Calder Hall and its small core presents problems associated both with heat transfer and with the effect of high temperature on the fuel elements.

These problems connected with the "fast breeder" reactor of the type being built at Dounreay were referred to by Sir John Cockcroft, Director of the Atomic Energy Research Establishment,

RAWSTHORNE'S
(Bolton) Limited
BULLOCK STREET WORKS, BOLTON.
Telephone: 1143 Established 1860

Jubo rubber drive

COUPLINGS

PIRELLI SAGA PATENT

SIMPLE to assemble

MODERN in design

RUGGED in use

Smooth power transmission.
Maximum absorption of torsional shock.
Compensation for possible misalignment.
Compensation for axial displacement.
Compensation for parallel displacement.
Minimum size and weight.
Maximum endurance without maintenance or replacement.
Ease of fitting and dismantling.
Safe in operation.

H.P. 1500 r.p.m.	PRICE
1.5	7/6
3.0	12/6
6.0	20/-
12.0	25/-

GEORGE SPENCER, MOULTON & CO LTD

ENGINEERS IN RUBBER SINCE 1848

BRADFORD-ON-AVON, WILTS.
TELEPHONE BRADFORD-ON-AVON 2216

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY
(INDUSTRIAL GROUP)
requires for
THE FIRST OF BRITAIN'S NUCLEAR POWER STATIONS
Sited at Calder Hall in Cumberland,

FIVE ENGINEERS

to control novel plant on a continuous shift system. Candidates should be over 25 years of age, have an Engineering degree or Corporate Membership of a Senior Engineering Institution and have had POWER PLANT experience. Ample opportunity will be given for training so that during silent hours, full responsibility can be taken. (Reference No. 1,004).

AN ELECTRICAL ENGINEER

is also required to assist the Works Engineer with maintenance. His main responsibility will be to supervise the electrical and instrument installations. Candidates should have served a recognised engineering apprenticeship and have Corporate Membership of the Institution of Electrical Engineers or equivalent qualifications and should have had appropriate experience. (Reference No. 1,005).

SALARY

for all posts will be assessed on the scale £1,065—£1,370 p.a. Additional allowances are payable for shift duties. All new entrants under the age of 55 automatically join the Authority's Pension Scheme. Houses will be available within a reasonable period for sucessful married candidates. Send a postcard for application form to:—

SENIOR RECRUITMENT OFFICER
U.K.A.E.A.
INDUSTRIAL GROUP HEADQUARTERS
RISLEY · WARRINGTON · LANCS

Quoting the appropriate reference number

THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY
(INDUSTRIAL GROUP)
has vacancies at Risley for

DESIGN ENGINEERS

to work on interesting and vital projects in connection with the development of Britain's industrial application of Nuclear Energy.

The successful applicants will be working in one of the Design Groups responsible for the pioneering of large industrial projects which may be either Nuclear Power Reactors or the associated Chemical Plants.

The work is often novel in character and is wide in scope, but designers experienced in high quality plant engineering or machine design should rapidly take an effective part in one of the Design Groups.

Applicants should have served a recognised engineering apprenticeship and have Corporate Membership of a senior Engineering Institution or equivalent qualifications.

SALARY

The range of salary covered is from
£1,065 to £1,620 per annum

The posts are permanent and new entrants under the age of 55 automatically join the Authority's Pension Scheme. Houses will be available within a reasonable time for successful candidates, if married. Annual leave allowance is six weeks.

Send a postcard for application form to :-
SENIOR RECRUITMENT OFFICER
U.K.A.E.A.
INDUSTRIAL GROUP HEADQUARTERS
RISLEY · WARRINGTON · LANCS
Quoting reference 1,016

when recently delivering the 61st James Forrest lecture to the Institution of Civil Engineers. He said that this type of reactor was a physicist's dream, but an engineer's nightmare, because of the quantity of heat that had to be extracted from a very small volume, and because bombardment with neutrons was very intense.

Whereas commercial generating stations based on the Calder Hall experiment could be built beginning about 1957, and begin operating about 1961, it is not anticipated that a commercial station of the fast reactor type can be tested in operation until 1965 at the earliest.

The work now being executed by John Thompson Limited for the Dounreay Station is quite separate from that which the Company is carrying out in collaboration with the Associated Electrical Industries Limited in the development of gas-cooled thermal reactor plant, such as will be used in the first commercial nuclear power stations.

The G. & T. Earle Group of the Associated Portland Cement Manufacturers Ltd. have placed with **Fraser & Chalmers Engineering Works** contracts for limestone crushing plant and a shale crushing plant, for their Cauldon project in Staffordshire.

A Dixie moving breaker and back plate hammer mill is being supplied for the shale crushing plant. The mill is direct coupled to a 300 hp motor and weighs some 34 tons. The machine is of a type whose general application is for the secondary crushing of sticky rocks and ores. Also included in the contract are a hopper, apron feeder, supporting steelwork and chutes.

For the limestone crushing plant a 72 in. × 19 ft. heavy duty rubber-mounted pan feeder is on order and the design of this feeder is such that it will withstand the shock of stone falling direct from 15 ton dumper trucks. A hopper, structural steel, chutes and access platforms are also included in this contract.

Electric traction equipment worth about £900,000 has been ordered from **Associated Electrical Industries (India) Ltd.** by Jessop & Co. Ltd., who are supplying one hundred and four railway coaches for broad gauge multiple-unit trains on the Calcutta electrification of the Indian Government Railway Board.

The new rolling stock will comprise thirty-four three-coach units, each consisting of two driving trailers with a motor coach between; two spare motor coaches have also been ordered.

The bulk of the electrical equipment will be made by **Metropolitan-Vickers Electrical Co. Ltd.** at their works at Sheffield and Trafford Park. Approximately 10 per cent. will be manufactured in India by A.E.I. Manufacturing Co. Ltd.

The all-steel coaches just ordered by the Toronto Transit Commission from the **Gloucester Railway Carriage and Wagon Co.** will be equipped as before with BTH electro-pneumatic camshaft control equipment. The present order for 34 cars follows the very satisfactory operation of the first 106 cars which went into service in Toronto in March 1954.

This form of BTH control equipment is fitted on the majority of motor coaches now operating on the surface and tube lines of London Transport, who have three 7-car trains now under construction as prototypes against future requirements. In this connection they have placed an order with BTH for fifteen PCM electro-pneumatic camshaft control equipments—to be of the same type as already in service on 1285 of their cars.

The General Electric Co. Ltd. announce that a contract has been received from the Ministry of Works for air compressor plant of 350,000 hp. The equipment is for extensive new Government research and testing facilities and comprises centrifugal compressors having combined turbine and synchronous motor drive.

Negotiations have been completed between the **Pesco Division of the Borg Warner Company** and **Plannair Limited,** Leatherhead, Surrey, for the manufacture under licence in America of axial flow fans and blowers.

The British company's equipment was subjected to rigorous tests and comparison by American engineers, and the outstandingly successful results achieved by this equipment in use with installation over there carefully analysed. Features of the Plannair units which particularly impressed Americans were the small size and weight—from 8 ozs.—compared with the large volume of air moved, and pressure achieved, as well as the low power consumption and its ability to operate in all types of climatic conditions without requiring frequent maintenance. The blower is of light alloy construction, withstanding shock as experienced in aircraft and vehicle work.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

PHYSICIST required for development on electronic temperature and humidity control in relation to process control. Prospects of becoming personal assistant to Development Engineer. Guildford, Surrey, district. Box No. 40.

SITUATIONS VACANT—*continued.*

NON-FERROUS FOUNDRY MANAGER (Directorship later) required, preferably experienced technically and commercially in centrifugal casting. Exceptional remuneration and an interest in financial results. Apply in confidence, Chairman, Metals & Alloys, Ltd., Minworth, Birmingham.

FERRANTI LIMITED, EDINBURGH

Engineers

Applications are invited for positions in our Production organisation which is engaged in the manufacture of precision electromechanical/electronic equipment. Applicants should hold a degree or diploma in Electrical Engineering, Mechanical Engineering or equivalent, but consideration will be given to applicants holding a H.N.C. in Engineering and who have completed an engineering apprenticeship. The vacancies are for :—

(A) **ENGINEERS** to work on the application of computer-controlled machine tools with reference to the utilisation of these in a production organisation, investigation into the material handling, setting, jigging and fixing methods to be employed with such machines :

(B) **PROJECT ENGINEERS** to take charge of the complete manufacture of complex electromechanical/electronic equipment—experience in production operations is essential in this case :

(C) **TECHNICAL PROJECT ENGINEERS** who do not possess the necessary practical experience for (B) but have a flair for production matters and who would act as technical assistants to the Project Engineers in the first instance with a view to promotion to Project Engineers in due course.

Salary according to age, qualifications and experience. Staff Pension Scheme. Ideal working conditions in modern factory furnished with the most modern equipment. Please address full details of technical qualifications, age and experience, and stating post applied for to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, quoting Ref. 71/F.E.

BEARINGS

BALL & ROLLER BEARINGS.—All Types and Sizes, Largest Stocks, Lowest Prices. Same day dispatch. **895-921 Fulham Rd., London, S.W.6.** Renown 6174 (Ext. 24).

WRITE TO:-

FURNACE DEPARTMENT

DAVID ETCHELLS & SON

LIMITED

DARLASTON · S. STAFFS

for particulars of their

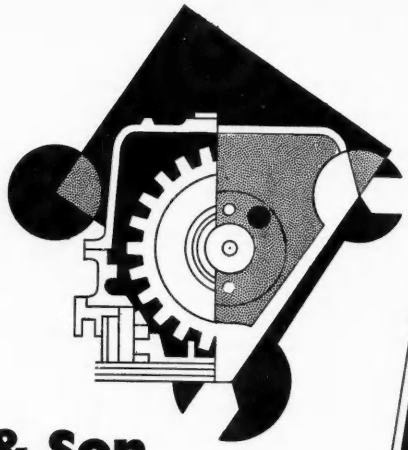
IMPROVED

C. C.

(CONCENTRATED COMBUSTION)

GAS BURNER

Smith's for Technical Books



Books on every aspect of engineering theory and practice, new techniques, and other specialized subjects can be quickly supplied by your local Smith's shop or bookstall.

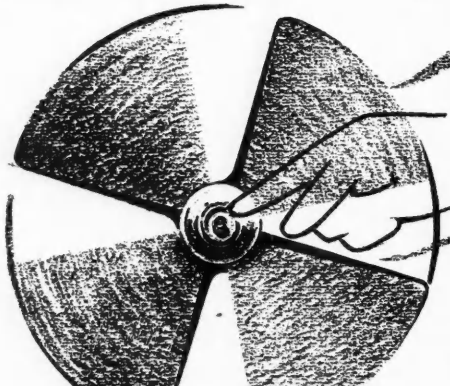
Your copies of ENGINEERS' DIGEST can be bound into attractive volumes; and all your stationery and printed matter supplied through our local branch.

W. H. Smith & Son

for SPECIALIST BOOKS

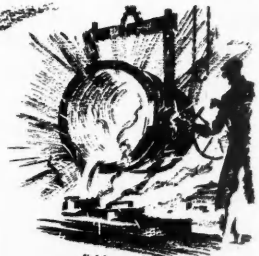
HEAD OFFICE: STRAND HOUSE, LONDON, W.C.2

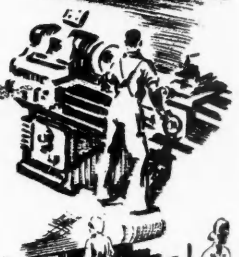
"Hot up" Summer production



By cooling!

The humid conditions found in many factories, offices and kitchens, etc. definitely slow down production, but cooling by adequate ventilation through well designed systems improves the efficiency and performance of all works operators.
In addition, many manufacturers use air to cool the goods they produce to avoid delay in handling, and to maintain quality.





★ *Fan Systems — Fume Exhaust Plants — Steam & Smoke Removal — Dust Exhausting — Ventilating Systems — Mechanical Draught — Blowing Systems for all processes — Drying Systems for all products.*

W. G. CANNON & SONS LTD.

3 Buckingham Palace Gardens, London, S.W.1. *Tel. SLOane 0639-0630*

Heating & Ventilating Engineers, Mechanical & Electrical Contractors

BOOKS RECEIVED

Magnetic Materials in the Electrical Industry. By P. R. Bardell. B.Sc., M.I.E.E., F.Inst.P., 258 pp., 158 illustrations. Publishers: Macdonald & Co. (Publishers), Ltd., 16 Maddox Street, London, W.1. Price: 32/6.

The aim of this book is to be of service to senior students in physics and electrical engineering and to physicists and engineers in industry. It successfully bridges the gap between an academic study of the properties of magnetic materials and the limited treatment of the subject possible in most textbooks for engineers; at the same time, it links the properties of materials with their applications.

The book should aid in promoting a better understanding of the properties of the large number of magnetic materials now available. Quite apart from the rather difficult nature of the subject, the position is obscured by the camouflage of proprietary names under which the identity of many commercially available materials is hidden, while the use of a wide variety of terms and units is an additional source of complexity. In this connection, an attempt has been made in this book to resolve some of these difficulties by including a glossary of terms and units, by the provision of tables showing the properties of materials, and by a note explaining magnetic terminology and units.

As Professor James Greig, M.Sc., Ph.D., M.I.E.E., S.M.I.R.E., points out in his foreword:—"... There is, in the authorship of this book, first-hand knowledge of the production, measurement, and application of certain classes of magnetic materials, which has been applied and extended to assessing critically the whole available range in explicit relation to their applications. This treatment brings out clearly that the full realisation of the high magnetic ...ies of the modern materials is closely interrelated with the ...gn of the systems in which they are to be utilised. ..."

Elementary Engineering Mechanics. By J. B. Thirlwell, B.Sc.(Eng.). 126 pp., 84 illustrations. Publishers: Macdonald & Co. (Publishers), Ltd., 16 Maddox Street, London, W.1. Price: 10/6.

The intention of this book is to help students who are approaching the subject of Mechanics for the first time, and, while it is directed towards students of instrument-making and horology, it is primarily a textbook of Mechanics. As such, it is intended not only for engineers who have to deal with heavy engineering and corresponding dimensions of great magnitude, but also for instrument-makers and horologists who, in their work, have to consider forces, torques, and distances which are often very small.

The book contains a comprehensive range of problems, which have been chosen as being of the correct scale for instrument-makers, though naturally there are examples drawn from other fields of engineering. In the earlier chapters rotary motion is dealt with, and a special effort is made to include many problems where the scale is very small. The later chapters include examples chosen directly from clocks and watches.

Engineering Inspection. Third Edition. By A. C. Parkinson, F...E.D., F.Inst.Mechs., A.C.P.(Hons.), F.Coll.H., etc. 172 pp., 155 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker House, Kingsway, London, W.C.2. Price: 10/-.

Originally published in 1940, when the war effort was approaching its peak, the scope of this book was deliberately planned to cover a fairly wide field on elementary lines. This new edition closely follows the same lines, without considerable extensions, though references to obsolete Standards, D.T.D.'s, Inspection Leaflets, etc. have been deleted. Furthermore, the section on British Standard Limits and Fits has been rewritten, to meet the requirements of B.S. 1916: 1953, etc.

Chapters in this interesting book, which may be considered an introduction to inspection work, including special reference to aero requirements, discuss the scope and functions of inspection departments; limits and tolerances; metals largely used in modern engineering; mechanical and other tests of materials; heat treatment and hardness testing; the elements of measurement; micrometers and verniers; precision measuring apparatus; commonly used gauges; threads and their measurement; the measurement of gears and angles; and the joining of metals by soldering, brazing, welding, and riveting. In addition, some British Standard Specifications useful to inspectors, gauge-makers, etc. are included.

The Commissioning of Electrical Plant and Associated Problems. Third Edition. By R. C. H. Richardson, B.E., A.M.I.E.E., A.A.I.E.E., A.M.N.Z.I.E. 456 pp., 196 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 50/-.

The commissioning of electrical plant covers a very wide area of the electrical-engineering field, thereby necessitating a thorough understanding of many practical and theoretical considerations. The behaviour of machines and apparatus, when put into commission for the first time, cannot be forecast completely and, although careful preliminary checking and preparation of plant will usually result in trouble-free performance, obtaining the initial operating characteristics will, in many respects, provide the most important guide to successful performance and life.

The object of the book, this third edition of which has been revised throughout and to which new information has been added in all sections, is to present general and precise information which has been found useful when commissioning both alternating- and direct-current generating, transforming, motive, and converting plant. This interesting publication (Vol. 5 in the series of Monographs on Electrical Engineering) will undoubtedly prove helpful to all those responsible for power-plant operation.

LATEST INDUSTRIAL LITERATURE

1. Chain Mechanisms. An extremely well-produced and illustrated 28-page booklet deals with the use of precision chain for purposes other than power transmission. As such, it demonstrates clearly and simply the wide variety of devices, motions, and operations for which standard chains, attachments, and wheels can be used to provide the basic mechanism.

This interesting booklet should prove of value to designers, demonstrating, as it does, the possibility of utilizing standard, easily available, and low-priced products for devices which might otherwise entail costly individual manufacture.

2. Diesel Engines for Rail Traction. A well-conceived and executed 12-page brochure describes and illustrates a range of diesel engines designed to meet railway requirements for robust, medium-speed units capable of direct coupling through a bell-housing member to a single-bearing traction-type generator. These engines are equally suitable for electric, mechanical, and hydraulic transmission and have a capacity for long, continuous service under heavy load conditions.

Developed on the 45° V-cylinder arrangement, these engines are available in 8-, 12-, and 16-cylinder sizes. Their short stroke enables a rotational speed of up to 1000 rpm to be run with reasonable piston speed, thus securing a high power/weight ratio and permitting generator diameter and weight to be kept low.

3. Silicone-Rubber Glass-Cloth Insulation Tape. A 4-page brochure describes the properties and advantages of a silicone-rubber glass-cloth insulation tape which retains its rubber-like properties at temperatures far above those which cause other rubbers to decompose. It may be operated at a continual working temperature of 250° C and will withstand a maximum of 300° C intermittently. All its dielectric properties are, however, maintained over this extensive temperature range.

The principal application of this invaluable electrical insulating material is in the electrical industry. In this field it exhibits many outstanding properties, including resistance to oxidation, corona attack, and electrical fatigue. The tape, as supplied, is semi-vulcanized and possesses sufficient tack to facilitate mechanical assembly. Sealing is completed by vulcanizing.

4. Universal Hydraulic Copying Equipment. A series of leaflets, neatly bound in a looseleaf folder, describes and illustrates a universal hydraulic duplicating attachment, which is a complete portable unit easily fitted to any standard machine tools, including lathes, shapers, planers, grinders, and boring machines.

The device, which uses simple sheet-metal templates, permits low-cost duplication of parts or contours on the face, diameter, or bore. The tracer bracket swivels through 360 deg., enabling 90-deg. angles and undercuts to be produced at high speed. Furthermore, the template can be set at a minimum distance from the tool, providing rigidity and accuracy in full view of the operator.

5. Battery-Electric Fork Trucks. Details are contained in a series of well-produced and illustrated brochures of a comprehensive range of battery-electric fork trucks, with many outstanding features, including robust construction, controlled acceleration, easy steering, dynamic braking, and inching control. The capacity of these trucks ranges from 2000 lb at 20 in. load centre to 6000 lb at 24 in. load centre.

In addition, a supplementary brochure describes a new technique in the palletless handling of unit loads, in the form of an attachment which replaces the normal fork carriage bars and consists of a load-carrying plate and push-pull rack fitted with a gripper blade.

6. Rigid Thermoplastic Material. In a neatly produced folder, a series of pamphlets describes a rigid thermoplastic material which is a specially blended and compounded form of straight unplasticized P.V.C., designed to provide good mechanical and thermal properties and excellent weldability, coupled with outstanding chemical resistance. The general grade of this material contains no plasticizer, filler, or pigment, and has a distinctive amber colour. A special, opaque grade is available for certain applications where opacity is required.

As particular care has been taken to include in its formulation only such additives as are accepted as harmless, this material is of special interest in applications where the question of toxicity may arise. It is normally available as a semi-finished product in the form of rigid pipe, tubing, solid rod, and welding rod, though other sections can be produced. In addition, a special adhesive, for making permanent joints in this material, has been produced.

MAIL THIS COUPON TO-DAY

THE ENGINEERS' DIGEST, 7.55
120, Wigmore Street, London, W.1.

Date.....

Please send free and without obligation the literature indicated by the following circled numbers:

1 2 3 4 5 6

Name .....

Position .....

Company .....

Address.....

Veeder-ROOT

GENERAL PURPOSE COUNTERS

Range includes—

- **RATCHET**
- **ROTARY RATCHET**
- **REVOLUTION and**
- **DIRECT DRIVE**
- **Operation Speeds up to 1000-5000 counts per minute**

Please write for illustrated Folder ED giving details of full range.

Representative will call on request.

COUNTERS FOR ALL PURPOSES

REGD. TRADE MARK

Veeder-ROOT LTD.

DUNDEE

Phone No. 85218

The Name that Counts!

London Office

20 PURLEY WAY
CROYDON, SURREY

Telephone

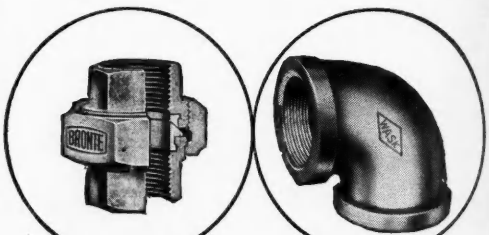
THORNTON HEATH 3477-8

MOULDED RUBBERS

OUR TECHNICAL STAFF WILL HELP AND ADVISE YOU

Dainite

THE HARBORO' RUBBER CO. LTD., Market Harborough. Tel: 2274-5



WASK

MALLEABLE IRON

PIPE FITTINGS

- **Individually air tested.**
- **British Standard taper pipe thread.**

WALTER SLINGSBY

AND COMPANY LIMITED

MIDLAND WORKS, KEIGHLEY

'Phone : 3749 *'Grams : "Malleable, Keighley."*

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *MANUFACTURE OF CORRUGATED TUBES*

Corrugated tubes are usually made from thin-walled smooth tubes, either by the rolling method, involving pressing the individual corrugations from the outside and from the inside, or by hydraulic hammering, involving total deformation of the smooth tube. Generally, such a corrugated tube is used as a spring, but it is not a true spring, inasmuch as it does not return completely to its original condition from its stressed condition. On the contrary, at each expansion of corrugated tubes, the material is brought nearer to the yield point, with the result that the life of such a tube is very limited in comparison with the practically unlimited life of a true spring. However, it is impossible to impart the properties of a true spring to a corrugated tube, because it cannot be given the conditions which are necessary for obtaining the action of a true spring. This would require very deep and numerous corrugations which, for reasons of manufacture, fitting, and cost, are impossible. It has been found that the elastic deformation of a corrugated tube is, during its operation, restricted substantially to the arcuate surfaces of the corrugations, and that it is only with respect to these that there is a possibility for improvement. It is claimed that a greatly improved corrugated tube may be produced by giving the tube a non-uniform wall thickness. According to a recent patent specification, this can be achieved in a very simple manner by compressing the corrugated tube until the corrugations rest against each other, the wall thickness of the exposed corrugated surfaces being then thinned by chemical or electrochemical means.

● *CAVITATION RESEARCH*

Although the phenomenon of cavitation has been of interest to hydraulic engineers for some time, it is only in recent years that this subject has gained the attention of physicists to any great extent. The approach has been mainly empirical, involving the close observation of the phenomena and study of the character of the destructive action. Various theories have been advanced to account for the extraordinary severity of cavitation damage. It is now generally accepted that this destructive action is of a mechanical nature, due either to the direct impact of water or the occurrence of high pressures in the neighbourhood of collapsing cavities. There is, however, at present no theory which adequately describes the mechanism. Indeed, the fundamental laws governing some of the factors involved are not yet fully understood. The properties of inertia, compressibility, and viscosity of water are involved; also, vaporization and condensation of water, expansion and contraction of the gas-filled cavity, heat conduction, surface tension, and diffusion of air into the cavity. The inception of cavitation at low vapour tension indicates the presence of gas nuclei in the water. Experiments indicate that the noise attendant upon the pulsations of bubbles decreases with increasing air content. It also appears likely that the damage caused by the collapse of a cavitation bubble is similarly related to the air content. Therefore, although the process of diffusion of air into the cavity probably has little effect upon the motion of the boundary of the cavity, the increase in air content during the pulsation of a bubble is of interest. A theoretical investigation of this problem has been made recently and numerical results have been obtained in the case of a strongly pulsing bubble. An interesting result was that the growth per period is relatively small, unless the bubble is extremely tiny or lies in the track of an ultrasonic beam.

● *PRODUCTION OF METALLIC TITANIUM*

A recent patent specification describes what is claimed to be an efficient method for the production of titanium metal by a fused-salt electrolytic process. The inventors state that in the many methods reported for the production of titanium there has been a failure to produce a metal of sufficient commercial purity to allow the metal to be either hot- or cold-worked, or fabricated. This is ascribed to the fact that these processes actually yield a compound of titanium with oxygen or hydrogen which is exceptionally hard and brittle. If these drawbacks could be eliminated, electrodeposition would be an attractive process for the recovery of titanium. The basic feature of the new process is claimed to involve electrolysis of a specially prepared bath containing a titanium ion in a valence less than four, under cover of an inert atmosphere. These baths consist of fused mixtures of reduced alkali fluotitanates in which the titanium has a valence of less than four, and one or more alkaline-earth or alkali halides, under conditions which avoid all embrittling agents. Alkaline-earth halides of calcium, magnesium, strontium, and barium may be used, while the alkali halides may be of potassium and sodium.

Meet Ethel Mary Sprott

It's mid-winter and she's sniffing because she's cold. She's fumbling because her fingers are frozen, she's fed up with the factory because it's like an ice-well. No heaters? Plenty! Trouble is, the building leaks heat like a sieve—especially through the roof! What's the answer? *

Factory-warming and fuel-saving in winter, cool-keeping in summer, peace and quiet-making all the year round—that's Fibreglass . . . rot-proof, everlasting, inexpensive, easily-installed Fibreglass insulation.

Meet Ethel Mary Sprott

It's mid-summer and she's sweating and swearing because she's hot. She's getting careless because she's drowsy. She's fed up because the factory's like an oven. What's the trouble? No windows or fans? Not on your life! Feel that roof. It's *baking* hot. No wonder production is slacking off. So what? So . . *

*wrap her in

FIBREGLASS
TRADE MARK

FIBREGLASS LIMITED, RAVENHEAD, ST. HELENS, LANCS. (ST. HELENS 4224). FACTORIES AT ST. HELENS, LANCS. AND POSSILPARK, GLASGOW

Optimum efficiency is claimed to be obtainable with sodium chloride or a mixture of sodium chloride and potassium chloride. If the bath consists of a eutectic mixture of sodium and potassium chlorides and potassium titanium fluoride, electrolysis may be carried out at 550 to 600 C. After the first electrolysis stage, the titanium is in a valence state of less than four, and, by increasing both voltage and current, a titanium metal sponge is deposited in a tightly adhering mass at the cathode.

● *MOLYBDENUM COMPOSITIONS OF IMPROVED STRENGTH*

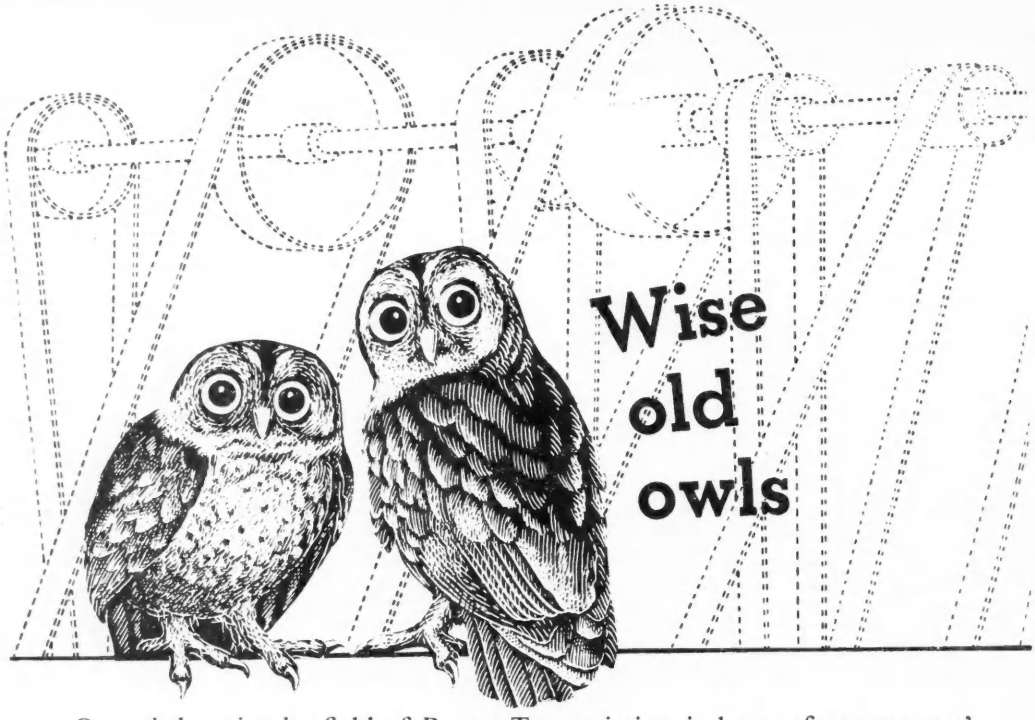
Progress in heat-engine design, particularly in the gas-turbine field, rests largely upon the availability of materials with ductility and resistance to mechanical and thermal shock, and high strength and stability above 1600 F. For this reason ceramic compositions are not fully satisfactory, and metals with outstanding high-temperature properties are needed. Molybdenum is the logical metal for such use because, in addition to its high-temperature properties, it is easily worked and is the most abundant of the very few materials with a very high melting point. A recent report indicates that a method has now been found for imparting greater strength to molybdenum for use at temperatures up to 2000 F. The new method involves the combination of molybdenum with fine dispersions of various oxides by powder-metallurgy techniques. The strength of the new molybdenum compositions may be gauged by comparing their behaviour in creep tests with that of metallic molybdenum alloys. Thus, the best of the metallic alloys prepared in the course of the investigation lasted 292·7 hours in a creep test at 25,000 psi at 1800 F. The best of the compositions containing oxides of zirconium, however, lasted 600 hours in a test at the same temperature. Moreover, the stress required to fracture the specimen had to be increased to 40,000 psi during the first 500 hours. The rupture strength of molybdenum at 1800 F can thus be increased three to four times by the dispersion in the metal of very small amounts of suitable oxides. It is stated that this is accomplished without adversely affecting hot workability or room-temperature ductility.

● *WELDING SPHEROIDAL-GRAPHITE CAST IRON*

Various methods are employed for welding ordinary cast iron. Normally, these welds are carried out with the aid of filler metals of various compositions giving a weld deposit which has a generally different metal composition to that of the parts welded. The mechanical properties of the weld deposit obtained in this way are similar to those of ordinary cast irons, i.e., they have a tensile strength of the order of 20 to 25 kg mm^2, and their elongation is often negligible. However, in the case of spheroidal-graphite cast irons, the mechanical properties of which are markedly superior, e.g., a tensile strength of 50 to 80 kg mm^2 with elongations up to some 20%, these welds are inadequate. A recent invention envisages elimination of this shortcoming by using a filler metal of cast iron with a carbon content of 2·5 to 4·5%, with at least 70% of the carbon content combined in the form of unstable carbides of iron and manganese, the balance being present in a free state in the form of simple nuclei of graphite. It is also stipulated that the filler metal must include a stabilizing agent for these carbides. Furthermore, this agent must be such as to act as a stabilizer only when it is in excess of a certain critical amount. The actual amount of stabilizer to be provided must exceed the critical amount to an extent less than the loss of stabilizing agent incurred during welding. Owing to this feature the filler metal will remain perfectly stable up to the moment of its use but, at the moment of welding, the melting of the filler metal occasions a decrease below the critical amount because of partial volatilization or chemical combination. Therefore, as soon as the unstable carbides decompose, the liberated graphite assembles around the nuclei of crystallization and forms spheroidal particles.

● *NEW APPROACH TO METAL-FORMING PROBLEMS*

A recent report on experimental stress analysis, as applied to the tubular extrusion process, contains important information on the technique employed and the stress distribution observed. In order to determine the flow pattern a newly developed technique, known as " visioplasticity," was employed. This method consists of rendering visual the motion of a plastic metal mass and determining particle velocity and direction. In order to determine the flow pattern of a plastically moving metallic mass, it is necessary to tag particles within the metal and to follow them during the deformation process. This has been done in the case of a solid cylindrical billet of lead, to be extruded into a tubular product, by sectioning the billet along a meridian plane and providing the billet on this plane with intersecting grid lines. The method of extruding a tubular product from a solid billet is not conventional, but permits comparison with results obtained with a solid extrusion. The grid line intersections were considered to represent particles whose motions must be determined. The direction and magnitude of velocity of the particles were determined by subjecting the billet to a series of small deformation steps and noting the displacement of the particles during these steps. Since the meridian plane is hidden from the observer's view when the billet is in the extrusion apparatus, it is necessary



Our wisdom in the field of Power Transmission is born of many years' experience in the manufacture of Belting. We know the answers to all the problems and because we make *ALL* types of Belting our advice is bound to be impartial. If you have a belt-drive problem, let us suggest the solution.

GRIPOLY
PRODUCTS

Sole Manufacturers :

LEWIS & TYLOR LTD.

Power Transmission Engineers

GRIPOLY MILLS · CARDIFF

And at Griffin Mills, Farnworth, Lancs. : Terminal House, Grosvenor Gardens, London, S.W.1

Makers of the world famous patent GRIPOLY Hair Belting GRIPOLATA Rubber and Canvas Ply Belting GRIPOLASTIC Rubber Impregnated Belting and many other GRIPOLY products.

to remove the billet from the apparatus between consecutive steps. It was found that the particle flow patterns in billets of commercially pure lead extruded into solid bars and tubes are substantially different for the same reduction in area. Also, the calculated axial compressive stresses and mean pressures in the billet during extrusion of a tube are the highest on the extrusion axis and on the chamber wall in the region near the orifice.

● *REINFORCED-PLASTIC COMPRESSOR BLADES*

It is reported that, although the development of reinforced-plastic blades for jet-engine compressors is still on an experimental basis, the third stage of a compressor rotor has been bladed with fibrous glass-reinforced blades. This development originated with the idea of finding a rapid and economical method of making prototype blades. A 100-hour run at rated engine speed is said to have been successfully completed on this rotor. Subsequent inspection of the blades showed that they were in excellent condition, with no signs of erosion or impending failure. Plastic blades appear to have several attractive properties. One point in their favour is that the fibrous glass-reinforced material gives the blade a relatively high damping capacity, keeping the stress low and making the blade less susceptible to fatigue failure. Another advantage is that the lightness of the blade improves the acceleration characteristics of the engine because of the resulting lower moment of inertia. Starting torque is also reduced. The plastic material exhibits practically no creep and therefore minimizes chances of stress rupture. Furthermore, the strength-to-weight ratio of the plastic material is about three times that of a compressor-blade steel. Relative to its mass, the impact strength of the plastic is equal to that of the blade steel. Disadvantages of the plastic blade are its non-isotropic strength properties and the difficulty of adequate inspection. It is now possible to produce fibrous glass-reinforced plastic materials capable of withstanding 500 F, but it is anticipated that phenolic-impregnated fibrous-glass plastics, capable of withstanding 700 F for about 10 hours, will soon become available.

● *INERT-GAS WELDING OF STATOR PACKS*

Electric-motor manufacturers are constantly striving to reduce manufacturing costs, and new methods of manufacturing, as well as new types of motors, are being designed to achieve this end. Welding, in one form or another, has been used by the electrical manufacturing industry for many years. Inert-gas arc welding with a relatively non-consumable tungsten electrode has been applied to the welding of stator laminations for a number of years and has proved the most successful of all the welding processes available. This process produces no spatter and requires no build-up above the surface of the stator. It provides excellent penetration and is used without fluxing materials which might contaminate the lamination adjacent to the weld zone. An inert-arc-welded stator produces a minimum of electrical loss and is of excellent mechanical stability. The process selection for inert-gas stator-pack welding is usually determined by the chemical composition of the steel used for laminations. Silicon is the principal element added to the electrical steels to produce the special electrical characteristics required. The grain growth produced by the silicon has a controlling influence on the hysteresis loss and to some degree on the eddy-current losses. The high silicon content, however, has an adverse effect on the ductility of a weld in the stator laminations. Brittle fracture occurs in the weld at room temperature when the silicon content exceeds $2\frac{1}{2}\%$. Therefore, steels containing silicon in excess of this amount require the addition of a low-carbon, low-silicon filler wire to prevent cracking. In the case of non-consumable tungsten electrodes, very low gas flow rates are claimed to yield excellent results, both from the economic and technical aspects, argon being used as the shielding gas.

● *NEW WIRE-ENAMELLING PROCESS*

On wires enamelled with a coating of the polyvinyl acetate type the enamelled coating is normally under tension because of the marked difference between the respective coefficients of thermal expansion of coating and copper wire. For this reason, in the case of wires coated with this type of plastic, the coating is always exposed to the danger of environmental cracking. This danger is, of course, greatly increased if the wire is bent or deformed. In the case of polyvinyl acetate resins it is the solvents used which are largely responsible for this phenomenon. It is especially interesting to note that environmental cracking also takes place in the presence of moisture. This can be demonstrated by bending a piece of coated wire after it has been wetted or immersed in water. On wires with a thin enamel coating the cracks are usually so small that they can be seen only under certain conditions of illumination; however, on thickly coated wires the cracks can be plainly seen, and detachment of the enamel film from the wire may even take place. It has been found that it is possible to provide effective protection of the polyvinyl enamel coating by applying a thin layer of an "oil-resinous enamel" to its surface. The precise composition of the protective coating must naturally be chosen in accordance with the kind of atmospheric conditions to which the wire is to be exposed. It is reported that an extensive study has been made of water-resisting oil-resinous enamels, and compositions are now available which have curing times that are practically equal to those of the polyvinyl resins.

90,000 STRESS REVERSALS PER HOUR — STILL 100 %

The Flexible supports of this Vibrating Spiral Elevator are made of PERMALI. As the unit operates on 50 c s A.C., in conjunction with a half-wave rectifier, the supports are flexed 25 times every second.
Despite the astronomical number of stress-reversals involved in months of continuous working, the PERMALI supports do not suffer from fatigue, or warp, and retain their full elasticity.

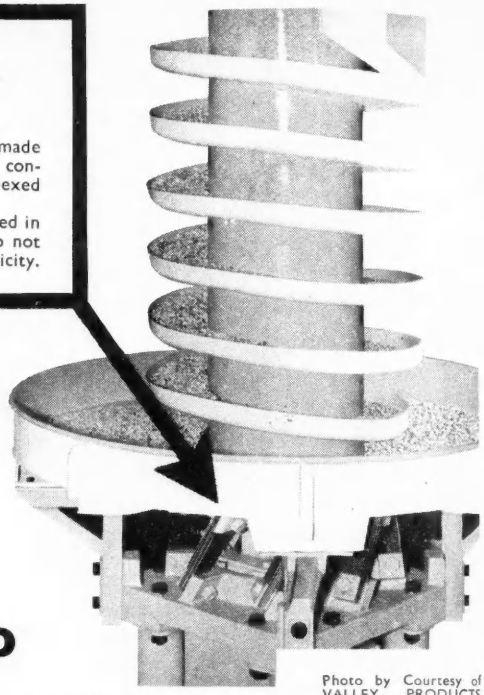


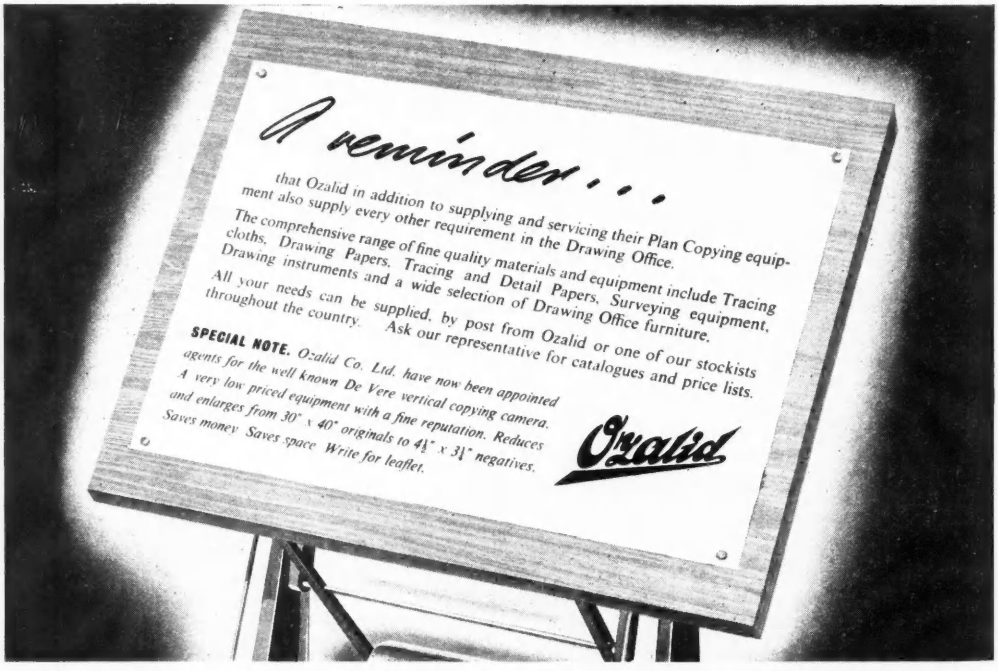
Photo by Courtesy of VALLEY PRODUCTS (LYE) LIMITED.

PERMALI is a light, strong and easily machined laminate. A good electrical insulator, it also has excellent resistance to Wear, Chemicals, Heat, Moisture, Weathering . . . and Termites !

★ENGINEERS interested in the possibilities of PERMALI should write NOW for (*a*) The latest Technical Information, or (*b*) Regular issues of Permali News.

PERMALI PERMALI **LIMITED**

GLOUCESTER, ENGLAND. *Tel.*: 24941. *Telegrams:* Permali Gloucester.


A reminder . . .
that Ozalid in addition to supplying and servicing their Plan Copying equipment also supply every other requirement in the Drawing Office.
The comprehensive range of fine quality materials and equipment include Tracing cloths, Drawing Papers, Tracing and Detail Papers, Surveying equipment, Drawing instruments and a wide selection of Drawing Office furniture.
All your needs can be supplied, by post from Ozalid or one of our stockists throughout the country. Ask our representative for catalogues and price lists.
SPECIAL NOTE. Ozalid Co. Ltd. have now been appointed agents for the well known De Vere vertical copying camera. A very low priced equipment with a fine reputation. Reduces and enlarges from 30" x 40" originals to 4⅛" x 31" negatives. Saves money. Saves space. Write for leaflet.
Ozalid

OZALID COMPANY LIMITED **62 London Wall, London, E.C.2.** **Tel : NATional 0551 (10 lines)**

● *MICROSCOPE HOT STAGE*

Although the value of the microscopic observation of metals at elevated temperatures has been well established, the general use of such studies has been limited because of the complexity of the equipment required. It has recently been pointed out, however, that it is quite possible to construct at a minimum of expense a microscope hot stage which will withstand normal laboratory usage and which can be operated by relatively inexperienced technicians. The hot stage described consists of four principal components, i.e., the furnace, the optical system, the cold trap, and the vacuum pumping group. The furnace section is so arranged that a visual access port for the microscope is positioned correctly for a bench-type microscope with a vertical camera. The furnace has a brass outer shell, which is water-cooled by a number of turns of copper tubing. A vitreosil plate, supported by a stainless steel ring, is arranged on the top of the furnace and provides visual observation of the specimen in the furnace. The resistance heating unit is an alundum tube wound with molybdenum wire. Inside the alundum tube is arranged a hollow stainless-steel column which supports the specimen. The hollow centre of this support accommodates a thermocouple for measuring the temperature of the specimen. The furnace is located directly above the diffusion pump. This location is advantageous because of the increased pumping speed and compactness of design, but it requires some type of baffle to prevent oil vapours from ascending into the furnace. For this purpose a liquid-nitrogen cold trap is placed between the diffusion pump and the furnace.

● *NEW HIGH-STRENGTH NYLON*

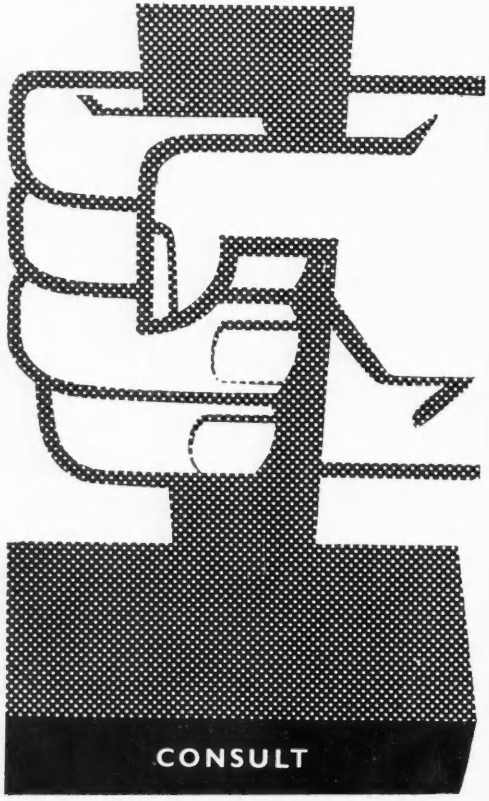
A new type of nylon has been developed which is particularly suitable for moulding operations and which, it is claimed, permits the commercial extrusion of transparent or translucent film and moulding of larger parts with thicker sections and without voids. This new material would therefore appear to be free from the disadvantage of ordinary nylon of being too solid to extrude below certain temperatures and being too fluid above the lowest workable temperature. The new nylon material is reported to have a relatively high molten viscosity, which minimizes problems of leakage from nozzles and joints and which makes the material particularly adaptable to blow moulding. The material is the first product from the chain development of a single monomer. It is formed by polymerizing caprolactam, which in turn is derived from cyclohexanone and hydroxylamine. The resin can be easily extruded to form film of varying degrees of translucency, in either oriented or unoriented state. Its mouldability is such that shapes such as bottles and complicated bodies can be formed on conventional moulding equipment. The properties of such mouldings are high strength, impact resistance, abrasion resistance, toughness, corrosion and solvent resistance, and self-lubricating characteristics against metals or other plastics. When moulded at low mould temperatures, the material attains maximum impact strength or toughness with minimum shrinkage. As the mould temperature increases the plastic becomes more rigid, but it is said to remain non-brittle at a mould temperature of 200° F. This effect is the result of controlled crystalline structure, which makes it possible to vary the physical properties of the material when moulding thin sections. In addition, thick sections can be moulded with minimum voids, since the nylon does not decompose or liberate gas during moulding or extrusion cycles.

● *MEASUREMENT OF SCAVENGING FLOW IN DIESEL-ENGINE CYLINDERS*

A recent research report states that the pitot sphere appears to be the most satisfactory instrument for carrying out a static investigation of the air flow through the cylinder of a two-stroke diesel engine. The instrument head of the pitot sphere used for this particular purpose is a brass hemisphere of 0·1 in. diameter, supported at the rear by a gooseneck arrangement which permits it to be inserted through a 0·2-in. opening. One small hole is drilled in the centre, while four holes are drilled approximately 42 deg. from the centre hole, two in the plane of the support shaft and two at 90 deg. from this plane. These five holes lead to five brass tubes, which transmit the pressure and serve as the support for the hemisphere. Connecting tubes lead up the steel support shaft and transmit the respective pressures to the manometers. The pitot sphere is stated to have the following three advantages over other point measuring devices:— Firstly, it can be calibrated in a low-turbulence wind tunnel and then used inside a cylinder where the turbulence intensity is high, without appreciable error. Secondly, the error due to transverse flow along the support shaft is negligible, and thirdly, the error when traversing through a steep velocity gradient is not serious because of the small diameter of the instrument. This is the major error and results in an apparent increase in flow through the cylinder. Integration of the velocity profile gives a 2 to 4% increase over the actual flow measured by an orifice meter. In a typical cylinder the difference in velocity across the 0·1 in. diameter sphere can amount to 8 feet per second, with the flow angle changing as much as 10 deg.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

For pressure die-castings



SPARKLETS

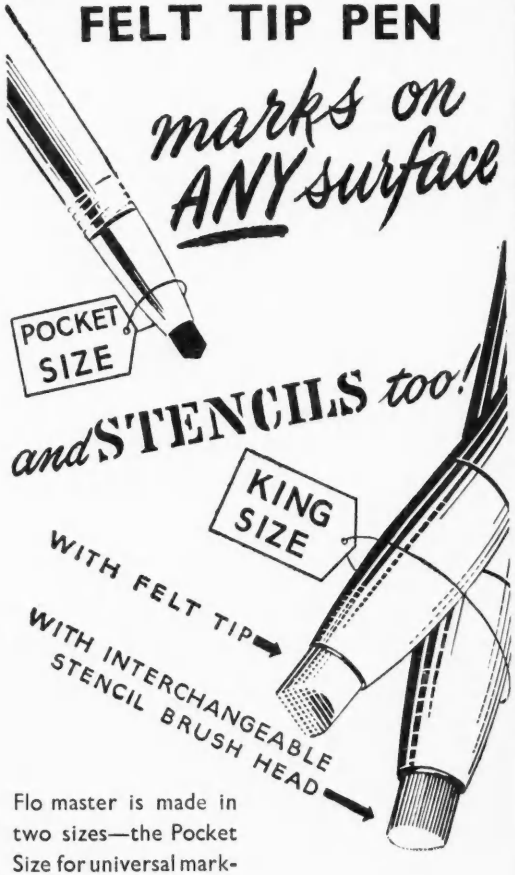
LIMITED

(DEPT. DA)
QUEEN STREET, LONDON, N.17

Flo-master

FELT TIP PEN

marks on ANY surface



Flo master is made in two sizes—the Pocket Size for universal marking in office and factory, and the King Size for heavy industrial use and for stencilling.

Fade-resistant inks available in 10 colours.

Interchangeable felt tips provided for different line thicknesses.

Send for illustrated leaflet.

CUSHMAN & DENISON CO., LTD.
DEPT. P., 124 VASSALL ROAD, LONDON, S.W.9
Telephone: RELiance 5268/9

r

e

d

t

TD.
.W.9

T